Gmsh
Gmsh Reference Manual

The documentation for Gmsh 4.5.4
A finite element mesh generator with built-in pre- and post-processing facilities

29 February 2020

Christophe Geuzaine
Jean-François Remacle
# Short Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obtaining Gmsh</td>
<td>1</td>
</tr>
<tr>
<td>Copying conditions</td>
<td>3</td>
</tr>
<tr>
<td>1 Overview</td>
<td>5</td>
</tr>
<tr>
<td>2 How to read this reference manual?</td>
<td>9</td>
</tr>
<tr>
<td>3 Running Gmsh on your system</td>
<td>11</td>
</tr>
<tr>
<td>4 General tools</td>
<td>21</td>
</tr>
<tr>
<td>5 Geometry module</td>
<td>37</td>
</tr>
<tr>
<td>6 Mesh module</td>
<td>47</td>
</tr>
<tr>
<td>7 Solver module</td>
<td>75</td>
</tr>
<tr>
<td>8 Post-processing module</td>
<td>77</td>
</tr>
<tr>
<td>9 File formats</td>
<td>111</td>
</tr>
<tr>
<td>A Tutorial</td>
<td>135</td>
</tr>
<tr>
<td>B Options</td>
<td>159</td>
</tr>
<tr>
<td>C Compiling the source code</td>
<td>243</td>
</tr>
<tr>
<td>D Gmsh API</td>
<td>249</td>
</tr>
<tr>
<td>E Information for developers</td>
<td>303</td>
</tr>
<tr>
<td>F Frequently asked questions</td>
<td>305</td>
</tr>
<tr>
<td>G Version history</td>
<td>313</td>
</tr>
<tr>
<td>H Copyright and credits</td>
<td>329</td>
</tr>
<tr>
<td>I License</td>
<td>333</td>
</tr>
<tr>
<td>Concept index</td>
<td>341</td>
</tr>
<tr>
<td>Syntax index</td>
<td>343</td>
</tr>
</tbody>
</table>
# Table of Contents

- Obtaining Gmsh ............................................. 1
- Copying conditions ........................................ 3

## 1 Overview .................................................. 5
  1.1 Geometry: model entity creation ............................ 5
  1.2 Mesh: finite element mesh generation ....................... 5
  1.3 Solver: external solver interface ........................... 6
  1.4 Post-processing: scalar, vector and tensor field visualization .... 6
  1.5 What Gmsh is pretty good at ................................ 7
  1.6 ... and what Gmsh is not so good at ........................ 8
  1.7 Bug reports .............................................. 8

## 2 How to read this reference manual? ..................... 9
  2.1 Syntactic rules used in the manual ......................... 9

## 3 Running Gmsh on your system ............................ 11
  3.1 Interactive mode ........................................ 11
  3.2 Non-interactive mode .................................... 12
  3.3 Command-line options .................................... 12
  3.4 Mouse actions .......................................... 16
  3.5 Keyboard shortcuts ...................................... 17

## 4 General tools .............................................. 21
  4.1 Comments ................................................. 21
  4.2 Expressions .............................................. 21
    4.2.1 Floating point expressions .......................... 21
    4.2.2 Character expressions ............................... 24
    4.2.3 Color expressions ................................... 25
  4.3 Operators ................................................. 25
  4.4 Built-in functions ..................................... 27
  4.5 User-defined macros .................................... 28
  4.6 Loops and conditionals .................................. 29
  4.7 General commands ...................................... 30
  4.8 General options ........................................ 35
Appendix A  Tutorial .............................. 135
  A.1 t1.geo ........................................... 135
  A.2 t2.geo ........................................... 136
  A.3 t3.geo ........................................... 138
  A.4 t4.geo ........................................... 140
  A.5 t5.geo ........................................... 142
  A.6 t6.geo ........................................... 145
  A.7 t7.geo ........................................... 146
  A.8 t8.geo ........................................... 146
  A.9 t9.geo ........................................... 149
  A.10 t10.geo .......................................... 150
  A.11 t11.geo .......................................... 152
  A.12 t12.geo .......................................... 153
  A.13 t13.geo .......................................... 154
  A.14 t14.geo .......................................... 155
  A.15 t15.geo .......................................... 156
  A.16 t16.geo .......................................... 157

Appendix B  Options .............................. 159
  B.1 General options list .............................. 159
  B.2 Geometry options list ........................... 189
  B.3 Mesh options list ............................... 198
  B.4 Solver options list ............................. 217
  B.5 Post-processing options list .................... 223

Appendix C  Compiling the source code ....... 243

Appendix D  Gmsh API ............................. 249
  D.1 Namespace gmsh: top-level functions .......... 250
  D.2 Namespace gmsh/option: option handling functions .... 252
  D.3 Namespace gmsh/model: model functions .......... 253
  D.4 Namespace gmsh/model/mesh: mesh functions .......... 259
  D.5 Namespace gmsh/model/mesh/field: mesh size field functions .......... 275
  D.6 Namespace gmsh/model/geo: built-in CAD kernel functions .. 276
  D.7 Namespace gmsh/model/geo/mesh: built-in CAD kernel meshing constraints .......... 281
  D.8 Namespace gmsh/model/occ: OpenCASCADE CAD kernel functions .......... 283
  D.9 Namespace gmsh/view: post-processing view functions .... 294
  D.10 Namespace gmsh/plugin: plugin functions .......... 297
  D.11 Namespace gmsh/graphics: graphics functions .......... 297
  D.12 Namespace gmsh/fltk: FLTK graphical user interface functions .......... 297
  D.13 Namespace gmsh/onelab: ONELAB server functions .... 299
  D.14 Namespace gmsh/logger: information logging functions .... 300
Appendix E  Information for developers .... 303
  E.1 Source code structure ........................................ 303
  E.2 Coding style ...................................................... 303
  E.3 Adding a new option ............................................. 304

Appendix F  Frequently asked questions .... 305
  F.1 The basics ......................................................... 305
  F.2 Installation problems ........................................... 305
  F.3 General questions ................................................ 306
  F.4 Geometry module ................................................ 307
  F.5 Mesh module ....................................................... 308
  F.6 Solver module ..................................................... 310
  F.7 Post-processing module ......................................... 310

Appendix G  Version history ...................... 313

Appendix H  Copyright and credits .............. 329

Appendix I  License ................................. 333

Concept index .............................................. 341

Syntax index ................................................. 343
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, ...).

Copy conditions

Gmsh is “free software”; this means that everyone is free to use it and to redistribute it on a free basis. Gmsh is not in the public domain; it is copyrighted and there are restrictions on its distribution, but these restrictions are designed to permit everything that a good cooperating citizen would want to do. What is not allowed is to try to prevent others from further sharing any version of Gmsh that they might get from you.

Specifically, we want to make sure that you have the right to give away copies of Gmsh, that you receive source code or else can get it if you want it, that you can change Gmsh or use pieces of Gmsh in new free programs, and that you know you can do these things.

To make sure that everyone has such rights, we have to forbid you to deprive anyone else of these rights. For example, if you distribute copies of Gmsh, you must give the recipients all the rights that you have. You must make sure that they, too, receive or can get the source code. And you must tell them their rights.

Also, for our own protection, we must make certain that everyone finds out that there is no warranty for Gmsh. If Gmsh is modified by someone else and passed on, we want their recipients to know that what they have is not what we distributed, so that any problems introduced by others will not reflect on our reputation.

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 333). 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 329.

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 249. 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 249) 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 249). 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 159), and can generate complex animations (see Chapter 4 [General tools], page 21, and Section A.8 [t8.geo], page 146);

- 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 243), 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 159);

• 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 303) 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 305, 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 135) 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 111), 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 249.

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 1.
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

```bash
> 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 135), 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.:

```bash
> 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 135, you can type the following command:

```bash
> 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 159. 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. For example, to mesh the first tutorial in batch mode, just type:

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

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

```plaintext
> 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

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

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

### 3.3 Command-line options

Geometry options:

- `-0` Output model, then exit
- `-tol value` Set geometrical tolerance
- `-match` Match geometries and meshes

Mesh options:

- `-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 243), 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)

-bin
   Create binary files when possible

-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

-part_weight tri|quad|tet|hex|pri|pyr|trih int
   Weight of a triangle/quad/etc. during partitioning

-part_split
   Save mesh partitions in separate files

-part_[no_.]topo
   Create the partition topology

-part_[no_.]ghosts
   Create ghost cells

-part_[no_.]physicals
   Create physical groups for partitions

-part_topo_pro
   Save the partition topology .pro file

-preserve_numbering_msh2
   Preserve element numbering in MSH2 format

-save_all
   Save all elements (discard physical group definitions)

-save_parametric
   Save nodes with their parametric coordinates

-save_topology
   Save model topology

-algo string
   Select mesh algorithm (meshadapt, del2d, front2d, delquad, del3d, front3d, mmg3d, pack, hxt)

-smooth int
   Set number of mesh smoothing steps
-order int
  Set mesh order (1, ..., 5)

-optimize[_netgen]
  Optimize quality of tetrahedral elements

-optimize_threshold
  Optimize tetrahedral elements that have a quality less than a threshold

-optimize_ho
  Optimize high order meshes

-ho_[min,max,nlayers]
  High-order optimization parameters

-clscale value
  Set global mesh element size scaling factor

-clmin value
  Set minimum mesh element size

-clmax value
  Set maximum mesh element size

-clcurv value
  Compute mesh element size from curvatures (value is the number of elements
  per 2*pi radians)

-aniso_max value
  Set maximum anisotropy (for bamg)

-smooth_ratio value
  Set smoothing ratio between mesh sizes at nodes of a same edge (for bamg)

-epslc1d value
  Set accuracy of evaluation of mesh size field for 1D mesh

-swapangle value
  Set the threshold angle (in degree) between two adjacent faces below which a
  swap is allowed

-rand value
  Set random perturbation factor

-bgm file
  Load background mesh from file

-check
  Perform various consistency checks on mesh

-ignore_periodicity
  Ignore periodic boundaries

Post-processing options:

-link int
  Select link mode between views (0, 1, 2, 3, 4)

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

Solver options:
-listen Always listen to incoming connection requests

-minterpreter string
  Name of Octave interpreter

-pyinterpreter string
  Name of Python interpreter

-run Run ONELAB solver(s)

Display options:

-n Hide all meshes and post-processing views on startup

-nodb Disable double buffering

-numsedges
  Set num of subdivisions for high order element display

-fontsize int
  Specify the font size for the GUI

-theme string
  Specify FLTK GUI theme

-display string
  Specify display

-camera Use camera mode view;

-stereo OpenGL quad-buffered stereo rendering (requires special graphics card)

-gamepad Use gamepad controller if available

Other options:

- -, -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

-pid Print process id on stdout

-watch pattern
  Pattern of files to merge as they become available

-bg file Load background (image or PDF) file

-v int Set verbosity level

-nopup Don’t popup dialog windows in scripts
-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

-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
- Toggle x coordinate freeze in geometry creation mode

y
- Toggle y coordinate freeze in geometry creation mode

z
- Toggle z coordinate freeze in geometry creation mode

**Shift+a**
- Bring all windows to front

**Shift+g**
- Show geometry options

**Shift+m**
- Show mesh options

**Shift+o**
- Show general options

**Shift+p**
- Show post-processing options

**Shift+s**
- Show solver options

**Shift+u**
- Show post-processing view plugins

**Shift+w**
- Show post-processing view options

**Shift+x**
- Move only along x coordinate in geometry creation mode
**Shift+y** Move only along y coordinate in geometry creation mode

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

**Shift+Escape**
Enable full mouse selection

**Ctrl+d** Attach/detach menu

**Ctrl+e** Export project

**Ctrl+f** Enter full screen

**Ctrl+i** Show statistics window

**Ctrl+j** Save model options

**Ctrl+l** Show message console

**Ctrl+m** Minimize window

**Ctrl+n** Create new project file

**Ctrl+o** Open project file

**Ctrl+q** Quit

**Ctrl+r** Rename project file

**Ctrl+s** Save mesh in default format

**Shift+Ctrl+c**
Show clipping plane window

**Shift+Ctrl+h**
Show current options and workspace window

**Shift+Ctrl+j**
Save options as default

**Shift+Ctrl+m**
Show manipulator window

**Shift+Ctrl+n**
Show option window

**Shift+Ctrl+o**
Merge file(s)

**Shift+Ctrl+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
<table>
<thead>
<tr>
<th>Key Combination</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt+e</td>
<td>Hide/Show element outlines for visible post-pro views</td>
</tr>
<tr>
<td>Alt+f</td>
<td>Change redraw mode (fast/full)</td>
</tr>
<tr>
<td>Alt+h</td>
<td>Hide/show all post-processing views</td>
</tr>
<tr>
<td>Alt+i</td>
<td>Hide/show all post-processing view scales</td>
</tr>
<tr>
<td>Alt+l</td>
<td>Hide/show geometry lines</td>
</tr>
<tr>
<td>Alt+m</td>
<td>Toggle visibility of all mesh entities</td>
</tr>
<tr>
<td>Alt+n</td>
<td>Hide/show all post-processing view annotations</td>
</tr>
<tr>
<td>Alt+o</td>
<td>Change projection mode (orthographic/perspective)</td>
</tr>
<tr>
<td>Alt+p</td>
<td>Hide/show geometry points</td>
</tr>
<tr>
<td>Alt+r</td>
<td>Loop through range modes for visible post-pro views</td>
</tr>
<tr>
<td>Alt+s</td>
<td>Hide/show geometry surfaces</td>
</tr>
<tr>
<td>Alt+t</td>
<td>Loop through interval modes for visible post-pro views</td>
</tr>
<tr>
<td>Alt+v</td>
<td>Hide/show geometry volumes</td>
</tr>
<tr>
<td>Alt+w</td>
<td>Enable/disable all lighting</td>
</tr>
<tr>
<td>Alt+x</td>
<td>Set X view</td>
</tr>
<tr>
<td>Alt+y</td>
<td>Set Y view</td>
</tr>
<tr>
<td>Alt+z</td>
<td>Set Z view</td>
</tr>
<tr>
<td>Alt+Shift+a</td>
<td>Hide/show small axes</td>
</tr>
<tr>
<td>Alt+Shift+b</td>
<td>Hide/show mesh volume faces</td>
</tr>
<tr>
<td>Alt+Shift+c</td>
<td>Loop through predefined colormaps</td>
</tr>
<tr>
<td>Alt+Shift+d</td>
<td>Hide/show mesh surface faces</td>
</tr>
<tr>
<td>Alt+Shift+l</td>
<td>Hide/show mesh lines</td>
</tr>
<tr>
<td>Alt+Shift+p</td>
<td>Hide/show mesh points</td>
</tr>
<tr>
<td>Alt+Shift+s</td>
<td>Hide/show mesh surface edges</td>
</tr>
<tr>
<td>Alt+Shift+t</td>
<td>Same as Alt+t, but with numeric mode included</td>
</tr>
<tr>
<td>Alt+Shift+v</td>
<td>Hide/show mesh volume edges</td>
</tr>
</tbody>
</table>
\texttt{Alt+Shift+x}
\hspace{1em} Set -X view

\texttt{Alt+Shift+y}
\hspace{1em} Set -Y view

\texttt{Alt+Shift+z}
\hspace{1em} 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 249) 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 metasyn-
tactic 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) |
```
Such expressions are used in most of Gmsh’s scripting commands. When \(~\{\text{expression}\})\) is appended to a string \text{string}, the result is a new string formed by the concatenation of \text{string}, \_ (an underscore) and the value of the \text{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,

\begin{verbatim}
For i In {1:3}
  x~{i} = i;
EndFor
\end{verbatim}

is the same as

\begin{verbatim}
x_1 = 1;
x_2 = 2;
x_3 = 3;
\end{verbatim}

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 \text{operator-unary-left}, \text{operator-unary-right}, \text{operator-binary}, \text{operator-ternary-left} and \text{operator-ternary-right} are defined in Section 4.3 [Operators], page 25. For the definition of \text{built-in-functions}, see Section 4.4 [Built-in functions], page 27. The various \text{real-options} are listed in Appendix B [Options], page 159. \text{Find} searches for occurrences of the first expression in the second (both of which can be lists). \text{StrFind} searches the first char-expression for any occurrence of the second char-expression. \text{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). \text{StrLen} returns the length of the string. \text{TextAttributes} creates attributes for text strings. \text{Exists} checks if a variable with the given name exists (i.e., has been defined previously), and \text{FileExists} checks if the file with the given name exists. \text{StringToName} creates a name from the provided string. \text{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). \text{GetValue} allows to ask the user for a value interactively (the second argument is the value returned in non-interactive mode). For example, inserting \text{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 \text{General.NoPopup} is set (see Section B.1 [General options list], page 159), no question is asked and the default value is automatically used.

\text{DefineNumber} allows to define a ONELAB variable in-line. The \text{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:

\begin{verbatim}
expression-list:
  expression-list-item <, expression-list-item> ...
\end{verbatim}
Chapter 4: General tools

with

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

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). \text{Unique} sorts the entries in the list and removes all duplicates. \text{Abs} takes the absolute value of all entries in the list. \text{ListFromFile} reads a list of numbers from a file. \text{LinSpace} and \text{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 \text{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 135]. 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-items.

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:

\[
\text{expression-list-or-all}
\]
\[
\text{expression-list} \mid :\]

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

### 4.2.2 Character expressions

Character expressions are defined as:

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

\text{Today} returns the current date. \text{OnelabAction} returns the current ONELAB action (e.g. check or compute). \text{GmshExecutableName} returns the full path of the Gmsh executable. \text{CurrentDirectory} (or \text{CurrentDir}) and \text{CurrentFileName} return the directory and file name of the script being parsed. \text{StrPrefix} and \text{StrRelative} take the prefix (e.g. to remove the extension) or the relative path of a given file name. \text{StrCat} and \text{Str} concatenate character expressions (\text{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 provided). 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-options are listed in Appendix B [Options], page 159. 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 146, for an interesting usage of char-expressions in an animation script.

List of character expressions are defined as:

\[
\text{char-expression-list}:
\text{char-expression} <,\ldots>
\]

4.2.3 Color expressions

Colors expressions are hybrids between fixed-length braced expression-lists and strings:

\[
\text{color-expression}:
\text{char-expression} |
\{ \text{expression, expression, expression} \} |
\{ \text{expression, expression, expression, expression} \} |
\text{color-option}
\]

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-options are listed in Appendix B [Options], page 159. See Section A.3 [t3.geo], page 138, 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. ~

---
\(^1\) The affectation operators are introduced in Section 4.7 [General commands], page 30.
3.  !, ++, --, - (unary)  
4.  *, /, %  
5.  +, -  
6.  <, >, <=, >=  
7.  ==, !=  
8.  &&  
9.  ||  
10.  =, +=, -=, *=, /= 

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 142, 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 142, 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:

\[ \text{string} = \text{expression}; \]

Creates a new expression identifier \text{string}, or affects \text{expression} to an existing expression identifier. The following expression identifiers are predefined (hard-coded in Gmsh’s parser):

\begin{itemize}
  \item \text{Pi} \quad \text{Returns 3.1415926535897932.}
  \item \text{GMSH_MAJOR_VERSION} \quad \text{Returns Gmsh’s major version number.}
  \item \text{GMSH_MINOR_VERSION} \quad \text{Returns Gmsh’s minor version number.}
  \item \text{GMSH_PATCH_VERSION} \quad \text{Returns Gmsh’s patch version number.}
  \item \text{MPI_Size} \quad \text{Returns the number of processors on which Gmsh is running. It is always 1, except if you compiled Gmsh with \textit{ENABLE_MPI} (see Appendix C [Compiling the source code], page 243).}
  \item \text{MPI_Rank} \quad \text{Returns the rank of the current processor.}
  \item \text{Cpu} \quad \text{Returns the current CPU time (in seconds).}
  \item \text{Memory} \quad \text{Returns the current memory usage (in Mb).}
  \item \text{TotalMemory} \quad \text{Returns the total memory available (in Mb).}
  \item \text{newp} \quad \text{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: \text{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 \textit{a priori} which tags are already attributed, and which ones are still available.}
  \item \text{newl} \quad \text{Returns the next available curve tag.}
  \item \text{news} \quad \text{Returns the next available surface tag.}
  \item \text{newv} \quad \text{Returns the next available volume tag.}
  \item \text{newll} \quad \text{Returns the next available curve loop tag.}
  \item \text{newsl} \quad \text{Returns the next available surface loop tag.}
  \item \text{newreg} \quad \text{Returns the next available region tag. That is, \text{newreg} returns the maximum of \text{newp, newl, news, newv, newll, newsl} and all physical group tags}.\footnote{For compatibility purposes, the behavior of \text{newl, news, newv} and \text{newreg} can be modified with the \textit{Geometry.OldNewReg} option (see Section B.2 [Geometry options list], page 189).}
\end{itemize}
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-lists 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 ex-  
  isting 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 ter-
   minal. 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 142, 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 expressions (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 159). 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 argument 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-options, real-options and color-options (in that order—check the default values to see the actual types) is given in Section B.1 [General options list], page 159. 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 gms/h/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 gms/h/model/geo and gms/h/model/occ namespaces in Appendix D [Gmsh API], page 249.

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 expressions 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 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 OpenCASCADE 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 omitted. 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 OpenCASCADE 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 consistently (using negative tags to specify reverse orientation). (Surface loops are used to create volumes: see Section 5.1.4 [Volumes], page 40.) With the OpenCASCADE kernel, the optional Using Sewing argument allows to build a shell made of surfaces that share geometrically identical (but topologically different) curves.

Physical Surface (expression | 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 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:`**

\[
\text{Extrude } \{ \text{expression-list} \} \{ \text{extrude-list} \}
\]

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.

\[
\text{Extrude } \{ \{ \text{expression-list} \}, \{ \text{expression-list} \}, \text{expression} \} \{ \text{extrude-list} \}
\]

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.

\[
\text{Extrude } \{ \{ \text{expression-list} \}, \{ \text{expression-list} \}, \{ \text{expression-list} \}, \text{expression} \} \{ \text{extrude-list} \}
\]

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.

\[
\text{Extrude } \{ \text{extrude-list} \}
\]

Extrudes entities in `extrude-list` using a translation along their normal. Only available with the built-in geometry kernel.

\[
\text{Extrude } \{ \text{extrude-list} \} \text{ Using Wire } \{ \text{expression-list} \}
\]

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

**`ThruSections:`**

\[
\text{ThruSections } \{ \text{expression-list} \}
\]

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

**`Ruled ThruSections:`**

\[
\text{Ruled ThruSections } \{ \text{expression-list} \}
\]

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

**`Fillet:`**

\[
\text{Fillet } \{ \text{expression-list} \} \{ \text{expression-list} \} \{ \text{expression-list} \}
\]

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

\texttt{extrude-list:}
\texttt{<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:

\begin{verbatim}
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]);
\end{verbatim}

This behaviour can be changed with the Geometry.ExtrudeReturnLateralEntities option (see Section B.2 [Geometry options list], page 189).

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:

\texttt{BooleanIntersection \{ boolean-list \} \{ boolean-list \}}
Computes the intersection of the object and the tool.

\texttt{BooleanUnion \{ boolean-list \} \{ boolean-list \}}
Computes the union of the object and the tool.

\texttt{BooleanDifference \{ boolean-list \} \{ boolean-list \}}
Subtract the tool from the object.

\texttt{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 expressions 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 expressions 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

\quad transform-list:
\quad \langle \text{Physical} \rangle \text{ Point | Curve | Surface | Volume}
\quad \{ \text{expression-list-or-all} \}; \ldots \ |
\quad \text{Duplicata} \{ \langle \text{Physical} \rangle \text{ Point | Curve | Surface | Volume}
\quad \{ \text{expression-list-or-all} \}; \ldots \ |
\quad \text{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 189). With the OpenCASCADE geometry 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 189.
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.SubdivisionAlgorithm option (see Section B.3 [Mesh options list], page 198).

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\(^5\).

---

Other experimental algorithms with specific features are also available. In particular, “Frontal-Delaunay for Quads” is a variant of the “Frontal-Delaunay” algorithm aiming at generating right-angle triangles suitable for recombination; and “BAMG” 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.

- The “HXT” algorithm is a new efficient and parallel reimplementatpon of the Delaunay algorithm.

- Other experimental algorithms with specific features are also available. In particular, “MMG3D” 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 243), 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.

---


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 111), 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 198) 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 249).

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 198), 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 111) 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 150.

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**
Maximum 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  Maximum 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
Chapter 6: Mesh module

**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

\[
X_{\text{min}} \leq x \leq X_{\text{max}} \land \ Y_{\text{min}} \leq y \leq Y_{\text{max}} \land \ Z_{\text{min}} \leq z \leq Z_{\text{max}}
\]

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
type: float
default value: 0

XAxis X component of the cylinder axis
type: float
default value: 0

XCenter X coordinate of the cylinder center
type: float
default value: 0

YAxis Y component of the cylinder axis
type: float
default value: 0

YCenter Y coordinate of the cylinder center
type: float
default value: 0

ZAxis Z component of the cylinder axis
type: float
default value: 1

ZCenter Z coordinate of the cylinder center
type: float
default value: 0

Distance Compute the distance 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):
```python
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):
```python
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 = 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) radiiues on both endpoints (1 and 2). Length scale is bilinearly interpolated between these locations (inner and outer radiiues, endpoints 1 and 2) The field values for a point P are given by: \( u = \Pi P \Pi P^2/11 \Pi P 11 \ r = 11 \ Pi P - u \Pi P^2 11 \ Ri = (1-u)^*Rli + u^*R2i \ Ro = (1-u)^*R1o + u^*R2o \ v = (r-Ri)/(Ro-Ri) \ lc = (1-v)^*( (1-u)^*v1i + u^*v2i ) + v^*( (1-u)^*v1o + u^*v2o ) \) where \((u,v) \in [0,1]x[0,1]\)

Options:

**R1_inner**
Inner radius of Frustum at endpoint 1
type: float
default value: 0
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Type</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1_outer</td>
<td>Outer radius of Frustum at endpoint 1</td>
<td>float</td>
<td>1</td>
</tr>
<tr>
<td>R2_inner</td>
<td>Inner radius of Frustum at endpoint 2</td>
<td>float</td>
<td>0</td>
</tr>
<tr>
<td>R2_outer</td>
<td>Outer radius of Frustum at endpoint 2</td>
<td>float</td>
<td>1</td>
</tr>
<tr>
<td>V1_inner</td>
<td>Element size at point 1, inner radius</td>
<td>float</td>
<td>0.1</td>
</tr>
<tr>
<td>V1_outer</td>
<td>Element size at point 1, outer radius</td>
<td>float</td>
<td>1</td>
</tr>
<tr>
<td>V2_inner</td>
<td>Element size at point 2, inner radius</td>
<td>float</td>
<td>0.1</td>
</tr>
<tr>
<td>V2_outer</td>
<td>Element size at point 2, outer radius</td>
<td>float</td>
<td>1</td>
</tr>
<tr>
<td>X1</td>
<td>X coordinate of endpoint 1</td>
<td>float</td>
<td>0</td>
</tr>
<tr>
<td>X2</td>
<td>X coordinate of endpoint 2</td>
<td>float</td>
<td>0</td>
</tr>
<tr>
<td>Y1</td>
<td>Y coordinate of endpoint 1</td>
<td>float</td>
<td>0</td>
</tr>
<tr>
<td>Y2</td>
<td>Y coordinate of endpoint 2</td>
<td>float</td>
<td>0</td>
</tr>
<tr>
<td>Z1</td>
<td>Z coordinate of endpoint 1</td>
<td>float</td>
<td>1</td>
</tr>
<tr>
<td>Z2</td>
<td>Z coordinate of endpoint 2</td>
<td>float</td>
<td>1.455171629957881e-152</td>
</tr>
</tbody>
</table>

**Gradient** Compute the finite difference gradient of Field[IField]:
Chapter 6: Mesh module

**F** = \((\text{Field}[\text{IField}](X + \Delta/2) - \text{Field}[\text{IField}](X - \Delta/2)) / \Delta\)

**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]:

\[
F = G(x+d,y,z) + G(x-d,y,z) + G(x,y+d,z) + G(x,y-d,z) + G(x,y,z+d) + G(x,y,z-d) - 6 \times G(x,y,z),
\]

where \(G=\text{Field}[\text{IField}]\) 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):

\[
F = \text{Field}[\text{IField}](\text{atan}(y/x) \text{, asin}(z/\sqrt{x^2+y^2+z^2}))
\]

**Options:**
FromStereo

- if = 1, the mesh is in stereographic coordinates. $\xi = \frac{2R_x}{R + z}$, $\eta = \frac{2R_y}{R + z}$
- type: integer
- default value: 0

IField

- Index of the field to evaluate.
- type: integer
- default value: 1

RadiusStereo

- radius of the sphere of the stereographic coordinates
- type: float
- default value: 6371000

MathEval

Evaluate a mathematical expression. The expression can contain $x$, $y$, $z$ for spatial coordinates, $F_0$, $F_1$, ... for field values, and and mathematical functions.

Options:

- $F$
  - Mathematical function to evaluate.
  - type: string
  - default value: "$F^2 + \sin(z)"

MathEvalAniso

Evaluate a metric expression. The expressions can contain $x$, $y$, $z$ for spatial coordinates, $F_0$, $F_1$, ... for field values, and and mathematical functions.

Options:

- $m_{11}$
  - element 11 of the metric tensor.
  - type: string
  - default value: "$F^2 + \sin(z)"

- $m_{12}$
  - element 12 of the metric tensor.
  - type: string
  - default value: "$F^2 + \sin(z)"

- $m_{13}$
  - element 13 of the metric tensor.
  - type: string
  - default value: "$F^2 + \sin(z)"

- $m_{22}$
  - element 22 of the metric tensor.
  - type: string
  - default value: "$F^2 + \sin(z)"

- $m_{23}$
  - element 23 of the metric tensor.
  - type: string
  - default value: "$F^2 + \sin(z)"

- $m_{33}$
  - element 33 of the metric tensor.
  - type: string
  - default value: "$F^2 + \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:

\[ F = \max\{\text{eig}(\text{grad}(\text{grad}(\text{Field}[IField])))\} \]
Options:

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

IField  Field index
type: integer
default value: 1

Mean
Simple smoother:

\[ F = \frac{(G(x+\delta,y,z) + G(x-\delta,y,z) + G(x,y+\delta,z) + G(x,y-\delta,z) + G(x,y,z+\delta) + G(x,y,z-\delta) + G(x,y,z))}{7}, \]
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 evaluation
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 "SetOutsideValue" 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 byte signed integers for \( n \), double precision floating points for \( v \), \( D \) and \( O \))  
type: boolean  
default value: 0

**Threshold**  
\[ \begin{align*} 
F &= \text{LCMin} \text{ if } \text{Field}[\text{IField}] \leq \text{DistMin}, \\
F &= \text{LCMax} \text{ if } \text{Field}[\text{IField}] \geq \text{DistMax}, \\
F &= \text{interpolation between LCMin and LCMax if } \text{DistMin} < \text{Field}[\text{IField}] < \text{DistMax} 
\end{align*} \]  
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 created in the (single) layer. In the second form, the first expression-list defines how many elements should be created in each extruded layer, and the second expression-list gives the normalized height of each layer (the list should contain a sequence of \( n \) numbers \( 0 < h_1 < h_2 < \ldots < h_n <= 1 \)). See Section A.3 [t3.geo], page 138, for an example.

For curve extrusions, the Recombine option will recombine triangles into quadrangles when possible. For surface extrusions, the Recombine option will recombine tetrahedra into prisms, hexahedra or pyramids.

Please note that, starting with Gmsh 2.0, region tags cannot be specified explicitly anymore in Layers commands. Instead, as with all other geometry commands, you must use the automatically created entity identifier created by the extrusion command. For example, the following extrusion command will return the tag of the new “top” surface in `num[0]` and the tag of the new volume in `num[1]`:

```
num[] = Extrude {0,0,1} { Surface{1}; Layers{10}; };
```

QuadTriNoNewVerts and QuadTriAddVerts allow to connect structured, extruded volumes containing quadrangle-faced elements to structured or unstructured tetrahedral volumes, by subdividing into triangles any quadrangles on boundary surfaces shared with tetrahedral volumes. (They have no effect for
1D or 2D extrusions.) **QuadTriNoNewVerts** subdivides any of the region’s quad-faced 3D elements that touch these boundary triangles into pyramids, prisms, or tetrahedra as necessary, all WITHOUT adding new nodes. **QuadTriAddVerts** works in a similar way, but subdivides 3D elements touching the boundary triangles by adding a new node inside each element at the node-based centroid. Either method results in a structured extrusion with an outer layer of subdivided elements that interface the inner, unmodified elements to the triangle-meshed region boundaries.

In some rare cases, due to certain lateral boundary conditions, it may not be possible to 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** 

```
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** 

```
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 interpolation. 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.

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 surface(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 specified between braces) to match the mesh of the master surface on the right-hand side (with boundary edges specified between braces). If used after meshing, generate the periodic node correspondence information assuming the mesh of the surface on the left-hand side effectively matches the mesh of the master surface on the right-hand side (useful for structured and extruded meshes). This operation triggers a synchronization of the CAD model with the internal Gmsh model.

Periodic Curve | Surface \{ expression-list \} = \{ expression-list \} Affine | Translate \{ expression-list \};

Force mesh of curves or surfaces on the left-hand side to match the mesh of the curves or surfaces on the right-hand side (masters), using prescribed geometrical transformations. If used after meshing, generate the periodic node correspondence information assuming the mesh of the curves or surfaces on the left-hand side effectively matches the mesh of the curves or surfaces on the right-hand side (useful for structured and extruded meshes). Affine takes a 4 x 4 affine transformation matrix given by row (only 12 entries can be provided for convenience); Translate takes the 3 components of the translation as in Section 5.1.7 [Transformations], page 44. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

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

Force the mesh of curves or surfaces on the left-hand side to match the mesh of the curves on the right-hand side (masters), using a rotation specified as in Section 5.1.7 [Transformations], page 44. 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;
Renumber the node tags in the current mesh in a continuous sequence.

RenumberMeshElements;
Renumber the elements tags in the current mesh in a continuous sequence.

< Recursive > Color color-expression { <Physical> Point | Curve | Surface | Volume { expression-list-or-all }; ... }
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 boundary, 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 198). 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.

Smother 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 Section B.3 [Mesh options list], page 198.
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 217. 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 111), 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 223).

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 146, and Section A.9 [t9.geo], page 149).

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 111.
8.1 Post-processing commands

This section describes the post-processing commands available in the scripting language. For the equivalent commands in the Gmsh API, see the `gmsh/view` module in Appendix D [Gmsh API], page 249.

**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 149, 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 140), 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 111, 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:

<table>
<thead>
<tr>
<th>type</th>
<th>#list-of-coords</th>
<th>#list-of-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scalar point</td>
<td>SP  3</td>
<td>1 * nb-time-steps</td>
</tr>
<tr>
<td>Vector point</td>
<td>VP  3</td>
<td>3 * nb-time-steps</td>
</tr>
<tr>
<td>Tensor point</td>
<td>TP  3</td>
<td>9 * nb-time-steps</td>
</tr>
<tr>
<td>Scalar line</td>
<td>SL  6</td>
<td>2 * nb-time-steps</td>
</tr>
<tr>
<td>Vector line</td>
<td>VL  6</td>
<td>6 * nb-time-steps</td>
</tr>
<tr>
<td>Tensor line</td>
<td>TL  6</td>
<td>18 * nb-time-steps</td>
</tr>
<tr>
<td>Scalar triangle</td>
<td>ST  9</td>
<td>3 * nb-time-steps</td>
</tr>
<tr>
<td>Vector triangle</td>
<td>VT  9</td>
<td>9 * nb-time-steps</td>
</tr>
<tr>
<td>Tensor triangle</td>
<td>TT  9</td>
<td>27 * nb-time-steps</td>
</tr>
<tr>
<td>Scalar quadrangle</td>
<td>SQ  12</td>
<td>4 * nb-time-steps</td>
</tr>
<tr>
<td>Vector quadrangle</td>
<td>VQ  12</td>
<td>12 * nb-time-steps</td>
</tr>
<tr>
<td>Tensor quadrangle</td>
<td>TQ  12</td>
<td>36 * nb-time-steps</td>
</tr>
<tr>
<td>Scalar tetrahedron</td>
<td>SS  12</td>
<td>4 * nb-time-steps</td>
</tr>
<tr>
<td>Vector tetrahedron</td>
<td>VS  12</td>
<td>12 * nb-time-steps</td>
</tr>
<tr>
<td>Tensor tetrahedron</td>
<td>TS  12</td>
<td>36 * nb-time-steps</td>
</tr>
<tr>
<td>Scalar hexahedron</td>
<td>SH  24</td>
<td>8 * nb-time-steps</td>
</tr>
<tr>
<td>Vector hexahedron</td>
<td>VH  24</td>
<td>24 * nb-time-steps</td>
</tr>
<tr>
<td>Tensor hexahedron</td>
<td>TH  24</td>
<td>72 * nb-time-steps</td>
</tr>
<tr>
<td>Scalar prism</td>
<td>SI  18</td>
<td>6 * nb-time-steps</td>
</tr>
<tr>
<td>Vector prism</td>
<td>VI  18</td>
<td>18 * nb-time-steps</td>
</tr>
<tr>
<td>Tensor prism</td>
<td>TI  18</td>
<td>54 * nb-time-steps</td>
</tr>
<tr>
<td>Scalar pyramid</td>
<td>SY  15</td>
<td>5 * nb-time-steps</td>
</tr>
<tr>
<td>Vector pyramid</td>
<td>VY  15</td>
<td>15 * nb-time-steps</td>
</tr>
<tr>
<td>Tensor pyramid</td>
<td>TY  15</td>
<td>45 * nb-time-steps</td>
</tr>
<tr>
<td>2D text</td>
<td>T2  3</td>
<td>arbitrary</td>
</tr>
<tr>
<td>3D text</td>
<td>T3  4</td>
<td>arbitrary</td>
</tr>
</tbody>
</table>

The coordinates are given ‘by node’, i.e.,

- (coord1, coord2, coord3) for a point,
- (coord1-node1, coord2-node1, coord3-node1, coord1-node2, coord2-node2, coord3-node2) for a line,
- (coord1-node1, coord2-node1, coord3-node1, coord1-node2, coord2-node2, coord3-node2, coord1-node3, coord2-node3, coord3-node3) for a triangle,
- etc.

The ordering of the nodes is given in Section 9.2 [Node ordering], page 119.

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,
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 \( f[i] = \text{Sum}(j=0, ..., d-1) F[i][j] p[j] \), with \( p[j] = u^*P[j][0] v^*P[j][1] w^*P[j][2] \) (\( u, v \) and \( w \) being the coordinates in the element’s parameter space), then val-coef-matrix denotes the \( d \times d \) matrix \( F \) and val-exp-matrix denotes the \( d \times 3 \) 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 \( g[i] = \text{Sum}(j=0, ..., m-1) G[i][j] q[j] \), with \( q[j] = u^*Q[j][0] v^*Q[j][1] w^*Q[j][2] \), then geo-coef-matrix denotes the \( m \times m \) matrix \( G \) and geo-exp-matrix denotes the \( m \times 3 \) matrix \( Q \).

Here are for example the interpolation matrices for a first order quadrangle:
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 223) 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 249).

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 \(\mu > \text{Hiding threshold}\), 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\}
Chapter 8: Post-processing module

- ICNMeasure = \{0, 1\}

- HidingThreshold = \([0, 1]\): Hides all element for which min(mu) is strictly greater than the threshold, where mu is ICN if ICNMeasure = 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 generates hexahedra, quadrangles, lines or points depending on the values of ‘NumPointsU’, ‘NumPointsV’ and ‘NumPointsW’.

   If ‘Boundary’ is zero, the plugin interpolates the view inside the box; otherwise the plugin interpolates the view at its boundary.

   If ‘View’ < 0, the plugin is run on the current view.

   Plugin(CutBox) creates one new 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
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:
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 mesh along 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 \([\text{MinU}, \text{MaxU}]\) and ‘NumPointsV’ values of the parameter v in \([\text{MinV}, \text{MaxV}]\).

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: \(2 \times \cos(u) \times \sin(v)\)

- **Y**
  Default value: \(4 \times \sin(u) \times \sin(v)\)

- **Z**
  Default value: \(0.1 + 0.5 \times \cos(v)\)

Numeric options:

- **Y2**
  Default value: 1

- **Z2**
  Default value: 0

- **NumPointsU**
  Default value: 20

- **NumPointsV**
  Default value: 20

- **ConnectPoints**
  Default value: 1

- **View**
  Default value: -1
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 ‘Ex-
  tractVolume’ < 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:

<table>
<thead>
<tr>
<th>Option</th>
<th>Default value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xc</td>
<td>0</td>
</tr>
<tr>
<td>Yc</td>
<td>0</td>
</tr>
<tr>
<td>Zc</td>
<td>0</td>
</tr>
<tr>
<td>R</td>
<td>0.25</td>
</tr>
</tbody>
</table>

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 and 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:

<table>
<thead>
<tr>
<th>Option</th>
<th>Default value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PhysicalPoint</td>
<td>0</td>
</tr>
<tr>
<td>PhysicalLine</td>
<td>0</td>
</tr>
</tbody>
</table>
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 ‘MinVal’ != ‘MaxVal’, it extracts the elements whose ‘TimeStep’-th values (averaged by element) are comprised between ‘MinVal’ and ‘MaxVal’. If ‘Visible’ != 0, it extracts visible elements.

If ‘View’ < 0, the plugin is run on the current view.

Plugin(ExtractElements) creates one new 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
over visible 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(LongitudeLatitude) projects the view ‘View’ in longitude-latitude.

If ‘View’ < 0, the plugin is run on the current view.

Plugin(LongitudeLatitude) 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 $w_0, w_1, w_2, ..., w_n$, 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{v_0^2+v_1^2+v_2^2}\$"

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
  OutputDimension
    Default value: 0
  OutputPhysicalGroup
    Default value: 2000

Plugin(MeshVolume)
  Plugin(MeshVolume) computes the volume of the mesh.

  Only the elements in the physical group ‘PhysicalGroup’ of dimension ‘Dimension’ are taken into account, unless ‘PhysicalGroup’ is negative, in which case all the elements of the given ‘Dimension’ are considered. If ‘Dimension’ is negative, all the elements are considered.

  Plugin(MeshVolume) creates one new 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:

<table>
<thead>
<tr>
<th>View</th>
<th>Default value: -1</th>
</tr>
</thead>
<tbody>
<tr>
<td>OverTime</td>
<td>Default value: 0</td>
</tr>
<tr>
<td>Argument</td>
<td>Default value: 0</td>
</tr>
<tr>
<td>Visible</td>
<td>Default value: 1</td>
</tr>
</tbody>
</table>

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

\[ A2 \cdot d^2X(t)/dt^2 + A1 \cdot dX(t)/dt + A0 \cdot X(t) = F \]

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
Chapter 8: Post-processing module

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

ViewX
Default value: -1

ViewY
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
Chapter 8: Post-processing module

ViewZ Default value: -1

Plugin(ShowNeighborElements)

Plugin(ShowNeighborElements) sets visible some elements and a layer of elements around them, the other being set invisible. Numeric options:

NumLayers Default value: 1
Element1 Default value: 0
Element2 Default value: 0
Element3 Default value: 0
Element4 Default value: 0
Element5 Default value: 0

Plugin(SimplePartition)

Plugin(SimplePartition) partitions the current mesh into ‘NumSlicesX’, ‘NumSlicesY’ and ‘NumSlicesZ’ slices along the X-, Y- and Z-axis, respectively. The distribution of these slices is governed by ‘MappingX’, ‘MappingY’ and ‘MappingZ’, where ‘t’ is a normalized absissa along each direction. (Setting ‘MappingX’ to ‘t’ will thus lead to equidistant slices along the X-axis.)

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(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:

<table>
<thead>
<tr>
<th>Option</th>
<th>Default value</th>
</tr>
</thead>
<tbody>
<tr>
<td>X0</td>
<td>0</td>
</tr>
<tr>
<td>Y0</td>
<td>0</td>
</tr>
<tr>
<td>Z0</td>
<td>0</td>
</tr>
<tr>
<td>X1</td>
<td>1</td>
</tr>
<tr>
<td>Y1</td>
<td>0</td>
</tr>
<tr>
<td>Z1</td>
<td>0</td>
</tr>
<tr>
<td>X2</td>
<td>0</td>
</tr>
<tr>
<td>Y2</td>
<td>1</td>
</tr>
<tr>
<td>Z2</td>
<td>0</td>
</tr>
<tr>
<td>NumPointsU</td>
<td>Default value: 10</td>
</tr>
<tr>
<td>NumPointsV</td>
<td>Default value: 1</td>
</tr>
<tr>
<td>DT</td>
<td>0.1</td>
</tr>
<tr>
<td>MaxIter</td>
<td>100</td>
</tr>
<tr>
<td>TimeStep</td>
<td>0</td>
</tr>
<tr>
<td>View</td>
<td>-1</td>
</tr>
<tr>
<td>OtherView</td>
<td>Default value: -1</td>
</tr>
</tbody>
</table>

Plugin(Summation)

Plugin(Summation) sums every time steps of 'Reference View' and (every) 'Other View X' and store the result in a new view.

If 'View 0' < 0 then the current view is selected.
If 'View 1...8' < 0 then this view is skipped.
Views can have different number of time steps

Warning: the Plugin assumes that every views share the same mesh and that meshes do not move between time steps! String options:
**Resulting 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

\[
\begin{bmatrix}
A_{11} & A_{12} & A_{13} & T_x \\
A_{21} & A_{22} & A_{23} & T_y \\
A_{31} & A_{32} & A_{33} & T_z \\
1 & 0 & 0 & 0
\end{bmatrix}
\]

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
Chapter 8: Post-processing module

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 223. See Section A.8 [t8.geo], page 146, and Section A.9 [t9.geo], page 149, for some examples.
Chapter 9: File formats

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 249 and Section E.1 [Source code structure], page 303 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 can¹ 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) ...
    numBoundingSurfaces(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) ...
umIntegerTags(ASCII int)
integerTag(ASCII int) ...
elemtag(size_t) value(double) ...
...
$EndElementData

$ElementNodeData
numStringTags(ASCII int)
stringTag(string) ...
numRealTags(ASCII int)
realTag(ASCII double) ...
umIntegerTags(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.
3-node second order line (2 nodes associated with the vertices and 1 with the edge).

6-node second order triangle (3 nodes associated with the vertices and 3 with the edges).

9-node second order quadrangle (4 nodes associated with the vertices, 4 with the edges and 1 with the face).

10-node second order tetrahedron (4 nodes associated with the vertices and 6 with the edges).

27-node second order hexahedron (8 nodes associated with the vertices, 12 with the edges, 6 with the faces and 1 with the volume).

18-node second order prism (6 nodes associated with the vertices, 9 with the edges and 3 with the quadrangular faces).

14-node second order pyramid (5 nodes associated with the vertices, 8 with the edges and 1 with the quadrangular face).

1-node point.

8-node second order quadrangle (4 nodes associated with the vertices and 4 with the edges).

20-node second order hexahedron (8 nodes associated with the vertices and 12 with the edges).

15-node second order prism (6 nodes associated with the vertices and 9 with the edges).

13-node second order pyramid (5 nodes associated with the vertices and 8 with the edges).

9-node third order incomplete triangle (3 nodes associated with the vertices, 6 with the edges).

10-node third order triangle (3 nodes associated with the vertices, 6 with the edges, 1 with the face).

12-node fourth order incomplete triangle (3 nodes associated with the vertices, 9 with the edges).

15-node fourth order triangle (3 nodes associated with the vertices, 9 with the edges, 3 with the face).

15-node fifth order incomplete triangle (3 nodes associated with the vertices, 12 with the edges).

21-node fifth order complete triangle (3 nodes associated with the vertices, 12 with the edges, 6 with the face).

4-node third order edge (2 nodes associated with the vertices, 2 internal to the edge).

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 119 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
"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 249).

• 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.

<table>
<thead>
<tr>
<th>Line:</th>
<th>Line3:</th>
<th>Line4:</th>
</tr>
</thead>
<tbody>
<tr>
<td>v \</td>
<td>v \</td>
<td>v  \</td>
</tr>
<tr>
<td>0----1 --&gt; u 0----2----1 0----2----3----1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Triangle:</th>
<th>Triangle6:</th>
<th>Triangle9/10:</th>
<th>Triangle12/15:</th>
</tr>
</thead>
<tbody>
<tr>
<td>v \</td>
<td>2 \</td>
<td>9 \</td>
<td></td>
</tr>
<tr>
<td>2 \</td>
<td>\</td>
<td>\</td>
<td></td>
</tr>
<tr>
<td>2 \</td>
<td>7 \</td>
<td>10 \</td>
<td></td>
</tr>
<tr>
<td>7 \</td>
<td>5 \</td>
<td>8 \</td>
<td></td>
</tr>
<tr>
<td>10 \</td>
<td>14 \</td>
<td>6 \</td>
<td></td>
</tr>
<tr>
<td>8 \</td>
<td>9 \</td>
<td>11 \</td>
<td></td>
</tr>
<tr>
<td>11 \</td>
<td>12 \</td>
<td>13 \</td>
<td></td>
</tr>
<tr>
<td>12 \</td>
<td>13 \</td>
<td>14 \</td>
<td></td>
</tr>
<tr>
<td>0----1 --&gt; u 0----3----1 0----3----4----1 0----3----4----5----1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 111. It is defined as follows:

```plaintext
$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
elem-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-numbers 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-numbers 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 111.

**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 119.

**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 $\text{InterpolationScheme}$ section (see below).

**number-of-real-tags**

gives the number of real number tags that follow. By default the first real-tag is interpreted as a time value associated with the dataset.

**number-of-integer-tags**

gives the number of integer tags that follow. By default the first integer-tag is interpreted as a time step index (starting at 0), the second as the number of field components of the data in the view (1, 3 or 9), the third as the number of entities (nodes or elements) in the view, and the fourth as the partition index for the view data (0 for no partition).

**number-of-nodes-per-elements**

gives the number of node values for an element in an element-based view.
value is a real number giving the value associated with a node or an element. For NodeData (respectively ElementData) views, there are ncomp values per node (resp. per element), where ncomp is the number of field components. For ElementNodeData views, there are ncomp times number-of-nodes-per-elements values per element.

number-of-element-topologies is the number of element topologies for which interpolation matrices are provided

elm-topology is the id tag of a given element topology: 1 for points, 2 for lines, 3 for triangles, 4 for quadrangles, 5 for tetrahedra, 6 for pyramids, 7 for prisms, 8 for hexahedra, 9 for polygons and 10 for polyhedra.

number-of-interpolation-matrices is the number of interpolation matrices provided for the element topology elm-topology. Currently you should provide 2 matrices, i.e., the matrices that specify how to interpolate the data (they have the same meaning as in Section 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!):

```plaintext
$MeshFormat
2.2 0 8
$EndMeshFormat
$Nodes
6
1 0.0 0.0 0.0
2 1.0 0.0 0.0
3 1.0 1.0 0.0
4 0.0 1.0 0.0
5 2.0 0.0 0.0
6 2.0 1.0 0.0
$EndNodes
$Elements
2
1 3 2 99 2 1 2 3 4
2 3 2 99 2 2 5 6 3
$EndElements
$NodeData
1
"A scalar view"
1
one string tag:
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
```
The binary file format is similar to the ASCII format described above:

```plaintext
$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:

```c
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 \( (4 + 3 \times \text{data-size}) \) bytes. For each node, the first 4 bytes contain the node number and the next \((3 \times \text{data-size})\) bytes contain the three floating point coordinates.

Here is a pseudo C code to write nodes-binary:

```c
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 \((3 \times 4)\) 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:

```c
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” \( (4 + \text{number-of-tags} \times 4 + \#\text{node-number-list} \times 4) \) bytes. For each element, the first four bytes contain the element number, the next \((\text{number-of-tags} \times 4)\) contain the tags, and the last \((\#\text{node-number-list} \times 4)\) contain the node indices.

Here is a pseudo C code to write elements-binary for triangles with the 2 standard tags (the physical and elementary regions):

```c
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 111. It is defined as follows:

```
$NOD
number-of-nodes
node-number x-coord y-coord z-coord
...
$ENDNOD
$ELM
```
number-of-elements
elm-number elm-type reg-phys reg-elem number-of-nodes node-number-list
...
$ENDELM

where

number-of-nodes
is the number of nodes in the mesh.

node-number
is the number (index) of the n-th node in the mesh; node-number must be a
positive (non-zero) integer. Note that the node-numbers do not necessarily have
to form a dense nor an ordered sequence.

x-coord y-coord z-coord
are the floating point values giving the X, Y and Z coordinates of the n-th node.

number-of-elements
is the number of elements in the mesh.

elm-number
is the number (index) of the n-th element in the mesh; elm-number must be a
positive (non-zero) integer. Note that the elm-numbers 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-node second order pyramid (5 nodes associated with the vertices, 8 with the edges and 1 with the quadrangular face).

1-node point.

8-node second order quadrangle (4 nodes associated with the vertices and 4 with the edges).

20-node second order hexahedron (8 nodes associated with the vertices and 12 with the edges).

15-node second order prism (6 nodes associated with the vertices and 9 with the edges).

13-node second order pyramid (5 nodes associated with the vertices and 8 with the edges).

See below for the ordering of the nodes.

$PostFormat
1.4 file-type data-size
$EndPostFormat

$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

reg-phys is the tag of the physical entity to which the element belongs; reg-phys must be a positive integer, or zero. If reg-phys is equal to zero, the element is considered not to belong to any physical entity.

reg-elem is the tag of the elementary entity to which the element belongs; reg-elem must be a positive (non-zero) integer.

number-of-nodes is the number of nodes for the n-th element. This is redundant, but kept for backward compatibility.

node-number-list is the list of the number-of-nodes node numbers of the n-th element. The ordering of the nodes is given in Section 9.2 [Node ordering], page 119.

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 Section 9.1 [MSH file format], page 111. It is defined as follows:
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:

\[
\begin{align*}
\text{coord1-node1} & \quad \text{coord1-node2} & \quad \text{coord1-node3} \\
\text{coord2-node1} & \quad \text{coord2-node2} & \quad \text{coord2-node3} \\
\text{coord3-node1} & \quad \text{coord3-node2} & \quad \text{coord3-node3} \\
\text{comp1-node1-time1} & \quad \text{comp2-node1-time1} & \quad \text{comp3-node1-time1} \\
\text{comp1-node2-time1} & \quad \text{comp2-node2-time1} & \quad \text{comp3-node2-time1} \\
\text{comp1-node3-time1} & \quad \text{comp2-node3-time1} & \quad \text{comp3-node3-time1} \\
\text{comp1-node1-time2} & \quad \text{comp2-node1-time2} & \quad \text{comp3-node1-time2} \\
\text{comp1-node2-time2} & \quad \text{comp2-node2-time2} & \quad \text{comp3-node2-time2} \\
\text{comp1-node3-time2} & \quad \text{comp2-node3-time2} & \quad \text{comp3-node3-time2} \\
\end{align*}
\]

The ordering of the nodes is given in Section 9.2 [Node ordering], page 119.

text2d
is a list of 4 double precision numbers:

\[
\begin{align*}
\text{coord1} & \quad \text{coord2} & \quad \text{style} & \quad \text{index} \\
\end{align*}
\]

where coord1 and coord2 give the X-Y position of the 2D string in screen coordinates (measured from the top-left corner of the window) and where index gives the starting index of the string in text2d-chars. If coord1 (respectively coord2) is negative, the position is measured from the right (respectively bottom) edge of the window. If coord1 (respectively coord2) is larger than 99999, the string is centered horizontally (respectively vertically). If style is equal to zero, the text is aligned bottom-left and displayed using the default font and size. Otherwise, style is converted into an integer whose eight lower bits give
the font size, whose eight next bits select the font (the index corresponds to the position in the font menu in the GUI), and whose eight next bits define the text alignment (0=bottom-left, 1=bottom-center, 2=bottom-right, 3=top-left, 4=top-center, 5=top-right, 6=center-left, 7=center-center, 8=center-right).

text2d-chars
is a list of nb-text2d-chars characters. Substrings are separated with the null ‘\0’ character.

text3d
is a list of 5 double precision numbers
\[ \text{coord1 coord2 coord3 style index} \]
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 129, 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:

```c
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\n$",  
""  
""  
""  
""  
""  
""  
""  
""  
view-name, nb-time-steps,  
"nb-scalar-points, nb-vector-points, nb-tensor-points, \n"nb-scalar-lines, nb-vector-lines, nb-tensor-lines, \n"nb-scalar-triangles, nb-vector-triangles, nb-tensor-triangles, \n"nb-scalar-quadrangles, nb-vector-quadrangles, nb-tensor-quadrangles, \n"nb-scalar-tetrahedra, nb-vector-tetrahedra, nb-tensor-tetrahedra, 
```
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 135. 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 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 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 is then 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').

// We can then define some additional points as well as our first curve. Curves // are Gmsh's second type of elementery entities, and, amongst curves, straight // lines are the simplest. A straight line is defined by a list of point // numbers. In the commands below, for example, the line 1 starts at point 1 and // ends at point 2:

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

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

// 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 a list of connected curves, a sign being
// associated with each curve (depending on the orientation of the curve):

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

// We can then define the surface as a list of curve loops (only one here, since
// there are no holes--see 't4.geo'):

Plane Surface(1) = {1} ;

// At this level, Gmsh knows everything to display the rectangular surface 6 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 those 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.)

// Here we define a physical curve that groups the left, bottom and right lines
// 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} ;

// Note that starting with Gmsh 3.0, models can be built using different
// 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. A rectangular surface could
// then simply be created with
//
// Rectangle(2) = {.2, 0, 0, 0.1, 0.3};
//
// See tutorial/t16.geo for a complete example, and demos/boolean for more.

A.2  t2.geo

//****************************************************************************
* Gmsh tutorial 2
* Includes, geometrical transformations, extruded geometries, physical groups (volumes)
********************************************************************************/

// We first include the previous tutorial file, in order to use it as a basis
// for this one:

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 units to the left with:

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

// 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 id. This id
// can be obtained using the graphical user interface by hovering the mouse over
// it and looking at the bottom of the graphic window: in this case, the new
// point has id "6". Point 6 can then be used to create new entities, e.g.:

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

// Using the graphical user interface to obtain the ids of newly created
// entities can sometimes be cumbersome. It can then be advantageous to use the
// return value of the transformation commands directly. For example, the
// Translate command returns a list containing the ids of the translated
// entities. For example, we can translate copies of the two surfaces 6 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) denotes a list, which in this case
// contains the ids 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]};). Note that list indexing starts at 0.

// 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;

// 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 list of all elementary entities. This can be achieved by
// selecting the 'File->Export->Gmsh unrolled geometry' menu or by typing
// > gmsh t2.geo -0
// on the command line.

// 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};

A.3 t3.geo

/********************************************
 * Gmsh 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;  
}  

// 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. Here the angle is specified as a 'parameter',  
// using the 'DefineConstant' syntax. This parameter can be modified  
// interactively in the GUI, and can be exchanged with other codes using the  
// ONELAB framework:  
DefineConstant[ angle = {90, Min 0, Max 120, Step 1,  
    Name "Parameters/Twisting angle"} ];  
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 programatically  
// 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 ids 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:  

// 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 tutorial 4
 * Built-in functions, surface holes, annotations, mesh 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);
sin = 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 , ssin , Lc2};
Point(16) = { -R1 / ssin , h5+R1*ccos , 0, Lc2};
Point(17) = { -e2 , 0.0 , 0, Lc1};
Point(18) = { -R2 , 0 , 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+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. 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@0.01x0,0,1,0,1,0" }; 

  // 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" }; 
};

// Views and geometrical entities can be made to respond to double-click events:

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 mesh entities:
A.5 t5.geo

/******************************************************************************
* Gmsh tutorial 5
* Characteristic lengths, arrays of variables, macros, loops
* ******************************************************************************/

// 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 1,300 nodes and 11,000
// tetrahedra. With
//
// > gmsh t5.geo -clscale 0.2
//
// the mesh counts approximately 350,000 nodes and 2.1 million 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};
Appendix A: Tutorial 143

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 number. This number is chosen as the
// highest current point number, plus one. (Note that, analogously to 'newp',
// the variables 'newl', 'news', 'newv' and 'newreg' select the highest number
// amongst currently defined curves, surfaces, volumes and 'any entities other
// than points', respectively.)

p1 = newp; Point(p1) = {x, y, z, 1car3} ;
p2 = newp; Point(p2) = {x+r,y, z, 1car3} ;
p3 = newp; Point(p3) = {x, y+r, z, 1car3} ;
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 = newreg; Circle(c1) = {p2,p1,p7}; c2 = newreg; Circle(c2) = {p7,p1,p5};
c3 = newreg; Circle(c3) = {p5,p1,p4}; c4 = newreg; Circle(c4) = {p4,p1,p2};
c5 = newreg; Circle(c5) = {p2,p1,p3}; c6 = newreg; Circle(c6) = {p3,p1,p5};
c7 = newreg; Circle(c7) = {p5,p1,p6}; c8 = newreg; Circle(c8) = {p6,p1,p2};
c9 = newreg; Circle(c9) = {p7,p1,p3}; c10 = newreg; Circle(c10) = {p3,p1,p4};
c11 = newreg; Circle(c11) = {p4,p1,p6}; c12 = newreg; Circle(c12) = {p6,p1,p7};

// We need non-plane surfaces to define the spherical holes. Here we use ruled
// surfaces, which can have 3 or 4 sides:

11 = newreg; Curve Loop(11) = {c5,c10,c4}; Surface(newreg) = {11};
12 = newreg; Curve Loop(12) = {c9,-c5,c1}; Surface(newreg) = {12};
13 = newreg; Curve Loop(13) = {c12,-c8,-c1}; Surface(newreg) = {13};
14 = newreg; Curve Loop(14) = {c8,-c4,c11}; Surface(newreg) = {14};
15 = newreg; Curve Loop(15) = {-c10,c6,c3}; Surface(newreg) = {15};
16 = newreg; Curve Loop(16) = {-c11,-c3,c7}; Surface(newreg) = {16};
17 = newreg; Curve Loop(17) = {-c2,-c7,-c12}; Surface(newreg) = {17};
18 = newreg; Curve Loop(18) = {-c6,-c9,c2}; Surface(newreg) = {18};

// 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] = newreg ;
Surface Loop(theloops[t]) = {18+1,15+1,11+1,12+1,13+1,17+1,16+1,14+1};
thehole = newreg ;
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]) = {35,31,29,37,33,23,39,25,27} ;

// 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[]} ;

// We finally define a physical volume for the elements discretizing the cube,
// without the holes (whose elements were already tagged with numbers 1 to 5 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;

// 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 tutorial 6
 * Transfinite meshes
 * ******************************************************************************/

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

// Delete the left line and replace it 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 surface Curve Loop(2) = {2, -1, l1, l2, l3, -3}; Plane Surface(1) = {-2};

// Put 20 points with a refinement toward the extremities on curve 2 Transfinite Curve{2} = 20 Using Bump 0.05;

// 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 points, but 20!) Transfinite Curve{l1} = 6; Transfinite Curve{l2} = 6; Transfinite Curve{l3} = 10;

// Put 30 points following a geometric progression on curve 1 (reversed) and on // curve 3 Transfinite Curve{-1,3} = 30 Using Progression 1.2;

// Define the Surface as transfinite, by specifying the four corners of the // transfinite interpolation Transfinite Surface{i} = {1,2,3,4};

// (Note that the list on the right hand side refers to points, not curves. When // the surface has only 3 or 4 points on its boundary the list can be // omitted. The way triangles are generated can be controlled by appending // "Left", "Right" or "Alternate" after the list.)

// Recombine the triangles into quads Recombine Surface{i};
// Apply an elliptic smoother to the grid
Mesh.Smoothing = 100;

Physical Surface(1) = 1;

// When the surface has only 3 or 4 control points, the transfinite constraint
// can be applied automatically (without specifying the corners explicitly).

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(11) = {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};
Physical Surface(2) = 15;

A.7 t7.geo

/***********************************************************/
/* Gmsh tutorial 7 */
/* 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.

// 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 tutorial 8 */
/* Post-processing, scripting, animations, options */
/***********************************************************/

// We first include 't1.geo' as well as some post-processing views:
Include "t1.geo";
Include "view1.pos";
Include "view1.pos";
Include "view4.pos";

// We then set some general options:

General.Trackball = 0;
General.RotationX = 0; General.RotationY = 0; General.RotationZ = 0;
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].AutoPosition = 0;
View[v2].PositionX = 85;
View[v2].PositionY = 50;
View[v2].Width = 200;
View[v2].Height = 130;

View[v3].Visible = 0;

// We then loop from 1 to 3 with a step of 1. (To use a different step, just add
// a third argument in the list. For example, ‘For num In {0.5:1.5:0.1}’ would
// increment num from 0.5 to 1.5 with a step of 0.1.)

t = 0;

For num In {1:3}

View[v0].TimeStep = t;
View[v1].TimeStep = t;
View[v2].TimeStep = t;
View[v3].TimeStep = t;
\[ t = (\text{View[v0].TimeStep < View[v0].NbTimeStep-1}) \ ? \ t+1 : 0; \]

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

\text{If (num == 3) } \quad \text{// We want to create 640x480 frames when num == 3:}
\text{General.GraphicsWidth = General.MenuWidth + 640;}
\text{General.GraphicsHeight = 480;}
\text{EndIf}

\text{frames = 50;}

\text{// It is possible to nest loops:}
\text{For num2 In \{1:frames\}}

\text{General.RotationX += 10;}
\text{General.RotationY = General.RotationX / 3;}
\text{General.RotationZ += 0.1;}
\text{Sleep 0.01; // sleep for 0.01 second}
\text{Draw; // draw the scene (one could use DrawForceChanged instead to force the}
\text{// reconstruction of the vertex arrays, e.g. if changing element}
\text{// clipping)}

\text{If (num == 3) } \quad \text{// The 'Print' command saves the graphical window; the 'Sprintf' function}
\text{// permits to create the file names on the fly:}
\text{// Print Sprintf("t8-%02g.gif", num2);}
\text{// Print Sprintf("t8-%02g.ppm", num2);}
\text{// Print Sprintf("t8-%02g.jpg", num2);}
\text{EndIf}

\text{EndFor}

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

\text{// with whirlgif:}
\text{//}*/
\text{System "whirlgif -minimize -loop -o t8.gif t8-*.gif";}
\text{*//}
\text{// with mpeg_encode (create parameter file first, then run encoder):}
\text{//}*/
\text{Printf("PATTERN I") > "t8.par";}
\text{Printf("BASE_FILE_FORMAT PPM") >> "t8.par";}
\text{Printf("GOP_SIZE 1") >> "t8.par";}
\text{Printf("SLICES_PER_FRAME 1") >> "t8.par";}
\text{Printf("PIXEL HALF") >> "t8.par";}
\text{Printf("RANGE 10") >> "t8.par";}
\text{Printf("PSEARCH_ALG EXHAUSTIVE") >> "t8.par";}
\text{Printf("BSEARCH_ALG CROSS2") >> "t8.par";}
\text{Printf("IQSCALE 1") >> "t8.par";}
\text{Printf("PQSCALE 1") >> "t8.par";}
\text{Printf("BQSCALE 25") >> "t8.par";}
\text{Printf("REFERENCE_FRAME DECODED") >> "t8.par";}
\text{Printf("OUTPUT t8.mpg") >> "t8.par";}
\text{Printf("INPUT_CONVERT ") >> "t8.par";}

Printf("INPUT_DIR 
") >> "t8.par";
Printf("INPUT") >> "t8.par";
tmp = Sprintf("t8-%02d.ppm", frames);
Printf(tmp) >> "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 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 a view, or create a new view
// 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 Ax+By+Cz+D=0), and then run it:
// 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 tutorial 10                                    *
*                                                      *
* General mesh size fields                             *
* *********************************************************/

// In addition to specifying target mesh sizes at the points of the
// geometry (see t1) or using a background mesh (see t7), 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) = {1.0,0.0,0,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].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].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.
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,
// 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 tutorial 11
* Unstructured quadrangular meshes
*******************************************************************************

// We have seen in tutorials t3 and t6 that extruded and transfinite meshes can
// be "recombined" into quads/prisms/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

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

A.12 t12.geo

/*****************************************************************************
* * Gmsh tutorial 12
* * Cross-patch meshing with compounds
* ****************************************************************************/

Compound geometrical entities can be defined to compute a new parametrization
of groups of elementary geometrical entities. This parametrization can then
be used for remeshing the compound as if it were a single CAD entity. See
J.-F. Remacle, C. Geuzaine, G. Compere and E. Marchandise. High-quality
surface remeshing using harmonic maps. International Journal for Numerical

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};

// The option "Mesh.CompoundClassify" can be used to choose how the compound
// surface mesh elements should be classified.

A.13  t13.geo

/***************************************************************************/
* Gmsh 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" ];

forceParametrizablePatches = DefineNumber[0, Choices{0,1},
   Name "Parameters/Create surfaces guaranteed to be parametrizable" ];

includeBoundary = 1;

ClassifySurfaces{angle * Pi/180, includeBoundary, forceParametrizablePatches};

// 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 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};

// element size 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 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}};


A.15 t15.geo

Embedded points, lines and surfaces

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;
Appendix A: Tutorial

// 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};
l1 = newl1;
Curve Loop(ll) = {l+1:l+4};
s = news;
Plane Surface(s) = {ll};
Surface{s} In Volume{1};

A.16 t16.geo

/***************************************************************************/
// Gmsh 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. Let us use the OpenCASCADE kernel:
SetFactory("OpenCASCADE");

// And let's build the same model as in t5.geo, but using constructive solid
// geometry:
Box(1) = {0,0,0, 1,1,1};
Box(2) = {0,0,0, 0.5,0.5,0.5};
BooleanDifference(3) = { Volume{1}; Delete; }{ Volume{2}; Delete; };
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
v() = BooleanFragments{ Volume{3}; Delete; }{ Volume{3 + 1 : 3 + 5}; Delete; };
Physical Volume(10) = v(#v()-1);

lcar1 = .1;
lcar2 = .0005;
lcar3 = .055;
eps = 1e-3;

Characteristic Length{ PointsOf{ Volume{:}; } } = lcar1;
Characteristic Length{ PointsOf{ Volume{3 + 1 : 3 + 5}; } } = lcar3;
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 are available in the demos/boolean directory.
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 249).

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: 4.5.3-git-cd30319d6; License: GNU General Public License; Build OS: MacOSX-sdk; Build date: 20200219;
Saved in: -

General.BuildOptions
Gmsh build options (read-only)
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
Appendix B: Options

**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: "4.5.3-git-cd30319d6"
Saved in: -
Appendix B: Options

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: -
Appendix B: Options

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
Appendix B: Options

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
Appendix B: Options

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
Appendix B: Options

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
Appendix B: Options

GeneralPointSize
Display size of points (in pixels)
Default value: 3
Saved in: General.OptionsFileName

GeneralPolygonOffsetAlwaysOn
Always apply polygon offset, instead of trying to detect when it is required
Default value: 0
Saved in: General.OptionsFileName

GeneralPolygonOffsetFactor
Polygon offset factor (offset = factor * DZ + r * units)
Default value: 0.5
Saved in: General.OptionsFileName

GeneralPolygonOffsetUnits
Polygon offset units (offset = factor * DZ + r * units)
Default value: 1
Saved in: General.OptionsFileName

GeneralProgressMeterStep
Increment (in percent) of the progress meter bar
Default value: 10
Saved in: General.OptionsFileName

GeneralQuadricSubdivisions
Number of subdivisions used to draw points or lines as spheres or cylinders
Default value: 6
Saved in: General.OptionsFileName

GeneralRotationX
First Euler angle (used if Trackball=0)
Default value: 0
Saved in: -

GeneralRotationY
Second Euler angle (used if Trackball=0)
Default value: 0
Saved in: -

GeneralRotationZ
Third Euler angle (used if Trackball=0)
Default value: 0
Saved in: -

GeneralRotationCenterGravity
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
Appendix B: Options

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: -
Appendix B: Options

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.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.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
Appendix B: Options

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.PostElementary
Save elementary region tags in mesh statistics exported as post-processing views
Default value: 1
Saved in: General.OptionsFileName

Print.PostElement
Save element numbers 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 per physical surface)
Default value: 1
Saved in: General.OptionsFileName
Appendix B: Options

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 per physical 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 geometry kernel? (If 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?
   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 number, 2: physical number)
   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 numbers?
   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.OCCDisableStl
Disable STL creation in OpenCASCADE kernel
Default value: 0
Saved in: General.OptionsFileName

Geometry.OCCFixDegenerated
Fix degenerated edges/faces when importing STEP, IGES and BRep models with the OpenCASCADE kernel
Default value: 0
Saved in: General.OptionsFileName

Geometry.OCCFixSmallEdges
Fix small edges when importing STEP, IGES and BRep models with the OpenCASCADE kernel
Default value: 0
Saved in: General.OptionsFileName

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

Geometry.OCCImportLabels
Import labels and colors when importing STEP models with the OpenCASCADE kernel
Default value: 1
Saved in: General.OptionsFileName

Geometry.OCCMakeSolids
Fix shells and make solids when importing STEP, IGES and BRep models with the OpenCASCADE kernel
Default value: 0
Saved in: General.OptionsFileName

Geometry.OCCParallel
Use multi-threaded OpenCASCADE boolean operators
Default value: 0
Saved in: General.OptionsFileName
Geometry.OCCScaling  
Scale STEP, IGES and BRep models by the given factor when importing them with the OpenCASCADE kernel  
Default value: 1  
Saved in: General.OptionsFileName

Geometry.OCCSewFaces  
Sew faces when importing STEP, IGES and BRep models with the OpenCASCADE kernel  
Default value: 0  
Saved in: General.OptionsFileName

Geometry.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 numbers?
  - Default value: 0
  - Saved in: General.OptionsFileName

Geometry.PointSelectSize
  - Display size of selected points (in pixels)
  - Default value: 6
  - Saved in: General.OptionsFileName

GeometryPointSize
  - 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
Appendix B: Options

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 numbers?
  - Default value: 0
  - Saved in: General.OptionsFileName

Geometry.SurfaceType
- Surface display type (0: cross, 1: wireframe, 2: solid)
  - 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? (not implemented yet)
Default value: 0
Saved in: General.OptionsFileName

Geometry.VolumeNumbers
Display volume numbers? (not implemented yet)
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
  entity, 3: by 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
Appendix B: Options

Mesh.Expode
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.Options.FileName

Mesh.Format
Default value: 10
Saved in: General.Options.FileName

Mesh.Hexahedra
Display mesh hexahedra?
Default value: 1
Saved in: General.Options.FileName

Mesh.HighOrderIterMax
Maximum number of iterations in high-order optimization pass
Default value: 100
Saved in: General.Options.FileName

Mesh.HighOrderNumLayers
Number of layers around a problematic element to consider for high-order optimization
Default value: 6
Saved in: General.Options.FileName

Mesh.HighOrderOptimize
Optimize high-order meshes? (0: none, 1: optimization, 2: elastic+optimization, 3: elastic, 4: fast curving)
Default value: 0
Saved in: General.Options.FileName

Mesh.HighOrderPassMax
Maximum number of high-order optimization passes (moving barrier)
Default value: 25
Saved in: General.Options.FileName
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: element number, 1: elementary entity number, 2: physical entity number, 3: partition number, 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
Appendix B: Options

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 numbers?
   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.MeshAlgorithm
    METIS partitioning algorithm 'ptype' (1: Recursive, 2: K-way)
    Default value: 1
    Saved in: General.OptionsFileName

Mesh.MeshEdgeMatching
    METIS edge matching type 'ctype' (1: Random, 2: Sorted Heavy-Edge)
    Default value: 2
    Saved in: General.OptionsFileName

Mesh.MeshMaxLoadImbalance
    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.MeshObjective
    METIS objective type 'objtype' (1: min. edge-cut, 2: min. communication
    volume)
    Default value: 1
    Saved in: General.OptionsFileName

Mesh.MeshMinConn
    METIS minimize maximum connectivity of partitions 'minconn' (-1: default)
    Default value: -1
    Saved in: General.OptionsFileName

Mesh.MeshRefinementAlgorithm
    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
Appendix B: Options

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 numbers?
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
Appendix B: Options

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
Appendix B: Options

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.OptionsFile Name

Mesh.SaveTopology
Save model topology in MSH2 output files (this is always saved in MSH3)
Default value: 0
Saved in: General.OptionsFile Name

Mesh.SaveParametric
Save parametric coordinates of nodes
Default value: 0
Saved in: General.OptionsFile Name

Mesh.SaveGroupsOfNodes
Save groups of nodes for each physical line and surface (for UNV, INP and Tochnog mesh formats)
Default value: 0
Saved in: General.OptionsFile Name

Mesh.ScalingFactor
Global scaling factor applied to the saved mesh
Default value: 1
Saved in: General.OptionsFile Name

Mesh.SecondOrderExperimental
Use experimental code to generate second order mesh
Default value: 0
Saved in: General.OptionsFile Name

Mesh.SecondOrderIncomplete
Create incomplete second order elements? (8-node quads, 20-node hexas, etc.)
Default value: 0
Saved in: General.OptionsFile Name

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.OptionsFile Name

Mesh.Smoothing
Number of smoothing steps applied to the final mesh
Default value: 1
Saved in: General.OptionsFile Name
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 (cur-
   rently 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 (cur-
   rently 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)
   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 numbers?
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 numbers?
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
Appendix B: Options

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
Appendix B: Options

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
Appendix B: Options

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
  Automatically 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
Appendix B: Options

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
ViewDoubleClickCommand
Command parsed when double-clicking on the view
Default value: ""
Saved in: General.OptionsFileName

ViewFileName
Default post-processing view file name
Default value: ""
Saved in: -

ViewFormat
Number format (in standard C form)
Default value: "%.3g"
Saved in: General.OptionsFileName

ViewGeneralizedRaiseX
Generalized elevation of the view along X-axis (in model coordinates, using formula possibly containing x, y, z, step, time, v0, ... v8)
Default value: "v0"
Saved in: General.OptionsFileName

ViewGeneralizedRaiseY
Generalized elevation of the view along Y-axis (in model coordinates, using formula possibly containing x, y, z, step, time, v0, ... v8)
Default value: "v1"
Saved in: General.OptionsFileName

ViewGeneralizedRaiseZ
Generalized elevation of the view along Z-axis (in model coordinates, using formula possibly containing x, y, z, step, time, v0, ... v8)
Default value: "v2"
Saved in: General.OptionsFileName

ViewGroup
Group to which this view belongs
Default value: ""
Saved in: General.OptionsFileName

ViewName
Default post-processing view name
Default value: ""
Saved in: -

ViewStipple0
First stippling pattern
Default value: "1*0xFF1F"
Saved in: General.OptionsFileName

ViewStipple1
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`
Appendix B: Options

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 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
Appendix B: Options

**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)
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: -

ViewNormals
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: -

ViewPointSize
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
Appendix B: Options

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
  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: -
Appendix B: Options

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
**Appendix B: Options**

**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**
Background 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:

```markdown
**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_CGNSS_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 (needed 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)
Appendix C: Compiling the source code

**ENABLE_MPEG_ENCODE**
Enable built-in MPEG movie encoder (default: ON)

**ENABLE_MPI**
Enable MPI (experimental, not used for meshing) (default: OFF)

**ENABLE_MVC_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 field (experimental) (default: OFF)

ENABLE_PACKAGE_STRIP
   Strip symbols in install packages to reduce install size (default: ON)

ENABLE_PARSER
   Enable GEO file parser (required for .geo/.pos 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 135 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 303):

- 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 111), 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 models1 (mesh-based data, as stored in MSH files: cf. Section 9.1 [MSH file format], page 111) 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` will lead to `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

---

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: \( \text{argc} = 0 \), \text{argv} = [], \text{readConfigFiles} = \text{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: \text{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: \text{fileName} \\
Output: - \\
Return: -

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

Input: \text{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

\textit{gmsh/option/setNumber}

Set a numerical option to \textit{value}. \textit{name} is of the form "category\_option" or "category[num]\_option". Available categories and options are listed in the Gmsh reference manual.

\begin{enumerate}
\item \textbf{Input:} \textit{name, value}
\item \textbf{Output:} -
\item \textbf{Return:} -
\end{enumerate}

\textit{gmsh/option/getNumber}

Get the \textit{value} of a numerical option. \textit{name} is of the form "category\_option" or "category[num]\_option". Available categories and options are listed in the Gmsh reference manual.

\begin{enumerate}
\item \textbf{Input:} \textit{name}
\item \textbf{Output:} \textit{value}
\item \textbf{Return:} -
\end{enumerate}

\textit{gmsh/option/setString}

Set a string option to \textit{value}. \textit{name} is of the form "category\_option" or "category[num]\_option". Available categories and options are listed in the Gmsh reference manual.

\begin{enumerate}
\item \textbf{Input:} \textit{name, value}
\item \textbf{Output:} -
\item \textbf{Return:} -
\end{enumerate}

\textit{gmsh/option(getString)}

Get the \textit{value} of a string option. \textit{name} is of the form "category\_option" or "category[num]\_option". Available categories and options are listed in the Gmsh reference manual.

\begin{enumerate}
\item \textbf{Input:} \textit{name}
\item \textbf{Output:} \textit{value}
\item \textbf{Return:} -
\end{enumerate}

\textit{gmsh/option/setColor}

Set a color option to the RGBA value \((r, g, b, a)\), where \(r, g, b\) and \(a\) should be integers between 0 and 255. \textit{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.

\begin{enumerate}
\item \textbf{Input:} \textit{name, r, g, b, a = 0}
\item \textbf{Output:} -
\item \textbf{Return:} -
\end{enumerate}
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:  -
Appendix D: Gmsh API

```c
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.
```
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 \texttt{dim} in the current model. Return the tag of the new discrete entity, equal to \texttt{tag} if \texttt{tag} is positive, or a new tag if \texttt{tag} < 0. \texttt{boundary} specifies the tags of the entities on the boundary of the discrete entity, if any. Specifying \texttt{boundary} allows Gmsh to construct the topology of the overall model.
Input: \texttt{dim}, \texttt{tag} = -1, \texttt{boundary} = []
Output: -
Return: integer value

gmsh/model/removeEntities
Remove the entities \texttt{dimTags} of the current model. If \texttt{recursive} is true, remove all the entities on their boundaries, down to dimension 0.
Input: \texttt{dimTags}, \texttt{recursive} = False
Output: -
Return: -

gmsh/model/removeEntityName
Remove the entity name \texttt{name} from the current model.
Input: \texttt{name}
Output: -
Return: -

gmsh/model/removePhysicalGroups
Remove the physical groups \texttt{dimTags} of the current model. If \texttt{dimTags} is empty, remove all groups.
Input: \texttt{dimTags} = []
Output: -
Return: -

gmsh/model/removePhysicalName
Remove the physical name \texttt{name} from the current model.
Appendix D: Gmsh API

Input: \text{name}  
Output: -  
Return: -  

\text{gmsh/model/getType} 
Get the type of the entity of dimension \text{dim} and tag \text{tag}.  
Input: \text{dim, tag}  
Output: \text{entityType}  
Return: -  

\text{gmsh/model/getParent} 
In a partitioned model, get the parent of the entity of dimension \text{dim} and tag \text{tag}, i.e. from which the entity is a part of, if any. \text{parentDim} and \text{parentTag} are set to -1 if the entity has no parent.  
Input: \text{dim, tag}  
Output: \text{parentDim, parentTag}  
Return: -  

\text{gmsh/model/getPartitions} 
In a partitioned model, return the tags of the partition(s) to which the entity belongs.  
Input: \text{dim, tag}  
Output: \text{partitions}  
Return: -  

\text{gmsh/model/getValue} 
Evaluate the parametrization of the entity of dimension \text{dim} and tag \text{tag} at the parametric coordinates \text{parametricCoord}. Only valid for \text{dim} equal to 0 (with empty \text{parametricCoord}), 1 (with \text{parametricCoord} containing parametric coordinates on the curve) or 2 (with \text{parametricCoord} containing pairs of u, v parametric coordinates on the surface, concatenated: \{p1u, p1v, p2u, ...\}). Return triplets of x, y, z coordinates in \text{points}, concatenated: \{p1x, p1y, p1z, p2x, ...\}.  
Input: \text{dim, tag, parametricCoord}  
Output: \text{points}  
Return: -  

\text{gmsh/model/getDerivative} 
Evaluate the derivative of the parametrization of the entity of dimension \text{dim} and tag \text{tag} at the parametric coordinates \text{parametricCoord}. Only valid for \text{dim} equal to 1 (with \text{parametricCoord} containing parametric coordinates on the curve) or 2 (with \text{parametricCoord} containing pairs of u, v parametric coordinates on the surface, concatenated: \{p1u, p1v, p2u, ...\}). For \text{dim} equal
to 1 return the x, y, z components of the derivative with respect to u \([d1ux, d1uy, d1uz, d2ux, ...]\); for \(\text{dim}\) equal to 2 return the x, y, z components of the derivative with respect to u and v: \([d1ux, d1uy, d1uz, d1vx, d1vy, d1vz, d2ux, ...]\).

Input: \(\text{dim}, \text{tag}, \text{parametricCoord}\)
Output: \(\text{derivatives}\)
Return: -

\text{gmsh/model/getCurvature}
Evaluate the (maximum) curvature of the entity of dimension \(\text{dim}\) and tag \(\text{tag}\) at the parametric coordinates \(\text{parametricCoord}\). Only valid for \(\text{dim}\) equal to 1 (with \(\text{parametricCoord}\) containing parametric coordinates on the curve) or 2 (with \(\text{parametricCoord}\) containing pairs of u, v parametric coordinates on the surface, concatenated: \([p1u, p1v, p2u, ...]\)).

Input: \(\text{dim}, \text{tag}, \text{parametricCoord}\)
Output: \(\text{curvatures}\)
Return: -

\text{gmsh/model/getPrincipalCurvatures}
Evaluate the principal curvatures of the surface with tag \(\text{tag}\) at the parametric coordinates \(\text{parametricCoord}\), as well as their respective directions. \(\text{parametricCoord}\) are given by pair of u and v coordinates, concatenated: \([p1u, p1v, p2u, ...]\).

Input: \(\text{tag}, \text{parametricCoord}\)
Output: \(\text{curvatureMax}, \text{curvatureMin}, \text{directionMax}, \text{directionMin}\)
Return: -

\text{gmsh/model/getNormal}
Get the normal to the surface with tag \(\text{tag}\) at the parametric coordinates \(\text{parametricCoord}\). \(\text{parametricCoord}\) are given by pairs of u and v coordinates, concatenated: \([p1u, p1v, p2u, ...]\). \text{normals} are returned as triplets of x, y, z components, concatenated: \([n1x, n1y, n1z, n2x, ...]\).

Input: \(\text{tag}, \text{parametricCoord}\)
Output: \(\text{normals}\)
Return: -

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

Input: \(\text{dim}, \text{tag}, \text{points}\)
Appendix D: Gmsh API

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 \texttt{numPart} partitions.
Input: \texttt{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 \texttt{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 \texttt{force} is set apply the optimization also to discrete entities. If \texttt{dimTags} is given, only apply the optimizer to the given entities.
Input: \texttt{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 \texttt{order}.
Input: \texttt{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 returnParametricCoord 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: \( \text{nodeTags, coord, parametricCoord} \)
Return: -

\text{gmsh/model/mesh/getNode}
Get the coordinates and the parametric coordinates (if any) of the node with tag \( \text{tag} \). 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: \( \text{nodeTag} \)
Output: \( \text{coord, parametricCoord} \)
Return: -

\text{gmsh/model/mesh/setNode}
Set the coordinates and the parametric coordinates (if any) of the node with tag \( \text{tag} \). 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: \( \text{nodeTag, coord, parametricCoord} \)
Output: -
Return: -

\text{gmsh/model/mesh/rebuildNodeCache}
Rebuild the node cache.
Input: \( \text{onlyIfNecessary = True} \)
Output: -
Return: -

\text{gmsh/model/mesh/getNodesForPhysicalGroup}
Get the nodes from all the elements belonging to the physical group of dimension \( \text{dim} \) and tag \( \text{tag} \). \( \text{nodeTags} \) contains the node tags; \( \text{coord} \) is a vector of length 3 times the length of \( \text{nodeTags} \) that contains the x, y, z coordinates of the nodes, concatenated: \( [n1x, n1y, n1z, n2x, ...] \).
Input: \( \text{dim, tag} \)
Output: \( \text{nodeTags, coord} \)
Return: -

\text{gmsh/model/mesh/addNodes}
Add nodes classified on the model entity of dimension \( \text{dim} \) and tag \( \text{tag} \). \( \text{nodeTags} \) contains the node tags (their unique, strictly positive identification numbers). \( \text{coord} \) is a vector of length 3 times the length of \( \text{nodeTags} \) that contains the x, y, z coordinates of the nodes, concatenated: \( [n1x, n1y, n1z, n2x, ...] \). The optional \( \text{parametricCoord} \) vector contains the parametric coordinates of the nodes, if any. The length of \( \text{parametricCoord} \) can be 0 or \( \text{dim} \) times the length of \( \text{nodeTags} \). If the \( \text{nodeTags} \) vector is empty, new tags are automatically assigned to the nodes.
Input: \[ \text{dim, tag, nodeTags, coord, parametricCoord} = [] \] 

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 \( \text{dim} \) and tag \( \text{tag} \) using their parametric coordinates. If \( \text{tag} < 0 \), relocate the nodes for all entities of dimension \( \text{dim} \). If \( \text{dim} \) and \( \text{tag} \) are negative, relocate all the nodes in the mesh.

Input: \[ \text{dim} = -1, \text{tag} = -1 \] 

Output: -

Return: -

**gmsh/model/mesh/getElements**

Get the elements classified on the entity of dimension \( \text{dim} \) and tag \( \text{tag} \). If \( \text{tag} < 0 \), get the elements for all entities of dimension \( \text{dim} \). If \( \text{dim} \) and \( \text{tag} \) are negative, get all the elements in the mesh. \( \text{elementTypes} \) contains the MSH types of the elements (e.g. 2 for 3-node triangles: see \( \text{getElementProperties} \) to obtain the properties for a given element type). \( \text{elementTags} \) is a vector of the same length as \( \text{elementTypes} \); each entry is a vector containing the tags (unique, strictly positive identifiers) of the elements of the corresponding type. \( \text{nodeTags} \) is also a vector of the same length as \( \text{elementTypes} \); 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: \[ \text{dim} = -1, \text{tag} = -1 \] 

Output: \( \text{elementTypes, elementTags, nodeTags} \) 

Return: -

**gmsh/model/mesh/getElement**

Get the type and node tags of the element with tag \( \text{tag} \). 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: \( \text{elementTag} \) 

Output: \( \text{elementType, nodeTags} \)
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 \(dim \geq 0\), 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 \(dim \geq 0\),
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 corre-
sponding 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, ...]`. 
gmsh/model/mesh/addElementsByType
Add elements of type elementType classified on the entity of tag tag. elementType 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]. integrationWeights 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
Appendix D: Gmsh API

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`. 
gmsh\_model\_mesh\_setSize

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

Input: \(\text{dimTags, size}\)

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: \(\text{tag, numNodes, meshType = "Progression", coef = 1.}\)

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". \(\text{cornerTags}\) 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 than 3 or 4 points on its boundary.

Input: \(\text{tag, arrangement = "Left", cornerTags = []}\)

Output: -

Return: -

gmsh\_model\_mesh\_setTransfiniteVolume

Set a transfinite meshing constraint on the surface *tag*. \(\text{cornerTags}\) can be used to specify the (6 or 8) corners of the transfinite interpolation explicitly.

Input: \(\text{tag, cornerTags = []}\)

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: \(\text{dim, tag}\)
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.
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 \texttt{dim} and tag \texttt{tags} as periodic copies of the meshes of entities \texttt{tagsMaster}, using the affine transformation specified in \texttt{affineTransformation} (16 entries of a 4x4 matrix, by row). If used after meshing, generate the periodic node correspondence information assuming the meshes of entities \texttt{tags} effectively match the meshes of entities \texttt{tagsMaster} (useful for structured and extruded meshes). Currently only available for \texttt{dim} == 1 and \texttt{dim} == 2.

Input: \texttt{dim, tags, tagsMaster, affineTransform}

Output: -

Return: -

gmsh/model/mesh/getPeriodicNodes
Get the master entity \texttt{tagMaster}, the node tags \texttt{nodeTags} and their corresponding master node tags \texttt{nodeTagsMaster}, and the affine transform \texttt{affineTransform} for the entity of dimension \texttt{dim} and tag \texttt{tag}.

Input: \texttt{dim, tag}

Output: \texttt{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 \texttt{tag} whose quality is lower than \texttt{quality}. If \texttt{tag} < 0, split quadrangles in all surfaces.

Input: \texttt{quality = 1.0, tag = -1}

Output: -

Return: -

gmsh/model/mesh/classifySurfaces
Classify ("color") the surface mesh based on the angle threshold \texttt{angle} (in radians), and create new discrete surfaces, curves and points accordingly. If \texttt{boundary} is set, also create discrete curves on the boundary if the surface is open. If \texttt{forReparametrization} is set, create edges and surfaces that can be reparametrized using a single map. If \texttt{curveAngle} is less than \texttt{pi}, also force curves to be split according to \texttt{curveAngle}.

Input: \texttt{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 `dims`; 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 `dims`; if empty, all bases are computed. Resulting basis representation cochains are stored as physical groups in the mesh.

Input: `domainTags = []`, `subdomainTags = []`, `dims = []`
Output: -
Return: -
Appendix D: Gmsh API

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 \((nx, ny, nz) \neq (0, 0, 0)\), 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 Bezier curve 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`
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.
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`
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" (refinement 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 "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/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: -
Appendix D: Gmsh API

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
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 \(\text{angle1}\) and \(\text{angle2}\) are specified, create a circle arc between the two angles. Return the tag of the circle.
Input:  \(x, y, z, r, \text{tag} = -1, \text{angle1} = 0., \text{angle2} = 2\pi\)
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 \(\text{angle1}\) and \(\text{angle2}\) 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:  \(x, y, z, r1, r2, \text{tag} = -1, \text{angle1} = 0., \text{angle2} = 2\pi\)
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.
Appendix D: Gmsh API

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 OpenCASCADE curve loop can be made of curves that share geometrically identical (but topologically different) points. If tag is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the curve loop.

Input:
curveTags, 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.
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.

\[
\text{Input: } x, y, z, dx, dy, dz, r1, r2, tag = -1, \text{angle = 2*pi} \\
\text{Output: } - \\
\text{Return: } \text{integer value}
\]

Add a torus, defined by its center \((x, y, z)\) and its 2 radii \(r1\) 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.

\[
\text{Input: } x, y, z, r1, r2, tag = -1, \text{angle = 2*pi} \\
\text{Output: } - \\
\text{Return: } \text{integer value}
\]

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.

\[
\text{Input: } wireTags, tag = -1, \text{makeSolid = True, makeRuled = False} \\
\text{Output: } outDimTags \\
\text{Return: } -
\]

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.

\[
\text{Input: } volumeTag, excludeSurfaceTags, offset, tag = -1 \\
\text{Output: } outDimTags \\
\text{Return: } -
\]
**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
gmsh/model/occ/affineTransform
Apply a general affine transformation matrix \( \mathbf{a} \) (16 entries of a 4x4 matrix, by row; only the 12 first can be provided for convenience) to the model entities \( \text{dimTags} \).

Input: \( \text{dimTags}, \mathbf{a} \)
Output: -
Return: -

gmsh/model/occ/copy
Copy the entities \( \text{dimTags} \); the new entities are returned in \( \text{outDimTags} \).

Input: \( \text{dimTags} \)
Output: \( \text{outDimTags} \)
Return: -

gmsh/model/occ/remove
Remove the entities \( \text{dimTags} \). If \text{recursive} is true, remove all the entities on their boundaries, down to dimension 0.

Input: \( \text{dimTags}, \text{recursive} = \text{False} \)
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 \( \text{dimTags} \) (or to all the entities in the model if \( \text{dimTags} \) is empty). Return the healed entities in \( \text{outDimTags} \).

Available healing options are listed in the Gmsh reference manual.

Input: \( \text{dimTags} = [], \text{tolerance} = 1e-8, \text{fixDegenerated} = \text{True}, \text{fixSmallEdges} = \text{True}, \text{fixSmallFaces} = \text{True}, \text{sewFaces} = \text{True}, \text{makeSolids} = \text{True} \)
Output: \( \text{outDimTags} \)
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 OpenCASCADE 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.
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.

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.

gmsh/view/remove
Remove the view with tag tag.

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.

gmsh/view/getTags
Get the tags of all views.
Appendix D: Gmsh API

**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 (\( \geq 0 \)) 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 associates 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 positive use it (and remove the view with that tag if it already exists), otherwise associate a new tag. Return the view tag.

Input: refTag, 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 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., xElementCoord = [], yElementCoord = [], zElementCoord = []
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/fltkinitialize**

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`. 
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:  -
gmsh/fltk/selectEntities
Select entities in the user interface. If \texttt{dim} is \textgreater{}= 0, return only the entities of the specified dimension (e.g. points if \texttt{dim} == 0).

\begin{itemize}
\item Input: \quad \texttt{dim} = -1
\item Output: \quad \texttt{dimTags}
\end{itemize}

Return: integer value

D.13 Namespace gmsh/onelab: ONELAB server functions

\begin{itemize}
\item \texttt{gmsh/onelab/set}
\quad Set one or more parameters in the ONELAB database, encoded in \texttt{format}.
\begin{itemize}
\item Input: \quad \texttt{data, format = "json"}
\item Output: \quad -
\item Return: \quad -
\end{itemize}
\end{itemize}

\begin{itemize}
\item \texttt{gmsh/onelab/get}
\quad Get all the parameters (or a single one if \texttt{name} is specified) from the ONELAB database, encoded in \texttt{format}.
\begin{itemize}
\item Input: \quad \texttt{name = ",", format = "json"}
\item Output: \quad \texttt{data}
\item Return: \quad -
\end{itemize}
\end{itemize}

\begin{itemize}
\item \texttt{gmsh/onelab/setNumber}
\quad Set the value of the number parameter \texttt{name} in the ONELAB database. Create the parameter if it does not exist; update the value if the parameter exists.
\begin{itemize}
\item Input: \quad \texttt{name, value}
\item Output: \quad -
\end{itemize}
\end{itemize}
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: -
Appendix D: Gmsh API

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 243 (see also Appendix F [Frequently asked questions], page 305).

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/PViewDataList.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 333 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 249). 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 243 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 antialiasing 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 146 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 activate 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 135) 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 \texttt{-format} option (e.g. \texttt{gmsh file.geo -format msh2 -2}).
• In a \texttt{.geo} script: add the line \texttt{Mesh.MshFileVersion = x.y}; for any version number \texttt{x.y}. You can also save this in your default options.
• In the API: \texttt{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 \texttt{.msh2} or \texttt{.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 \texttt{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 \texttt{demos/api/faces.cpp}.

\section*{F.6 Solver module}

1. How do I integrate my own solver with Gmsh?

Gmsh uses the ONELAB interface (\url{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 \texttt{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 \texttt{-listen} command line option), and Gmsh will always listen for your program on the \texttt{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 \texttt{custom_gui.py} and \texttt{custom_gui.cpp}) for examples.

\section*{F.7 Post-processing module}

1. How do I compute a section of a plot?

Use ‘Tools-&gt;Plugins-&gt;Cut Plane’.

2. Can I save an isosurface to a file?

Yes: first run ‘Tools-&gt;Plugins-&gt;Cut Map’ to extract the isosurface, then use ‘View-&gt;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 146 or demos/post_processing/anim.script for some examples.
10. Is there a way to visualize only certain components of vector/tensor fields?

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

4.5.4 (February 29, 2020): periodic mesh optimization now ensures that the master mesh is not modified; code cleanup; API tutorials; 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 algorithms 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 file); 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 explicitely; 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-Delaunay 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 BooleanFragnents); 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.

3.0.0 (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.


2.14.0 (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.


2.13.0 (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+O 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.
Appendix G: Version history

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 reproducibility 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 affine 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 reproducibility 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.


2.8.0 (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.


2.6.0 (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 GMSHi; 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; 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
Appendix G: Version history

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, ViewNormals, 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 sma 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 recomposed/non-recomposed 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 recomposed+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

Gmsh is copyright (C) 1997-2020

Christophe Geuzaine
<cgeuzaine at uliege.be>

and

Jean-Francois Remacle
<jean-francois.remacl at uclouvain.be>

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 Lambrechts (mesh size fields, solver, Python wrappers), Jozef Vesely (old Tetgen integration), Koen Hillewaert (high order elements, generalized periodic meshes), Laurent Stainier (eigenvalue solvers, tensor display and help with MacOS port), Marc Ume (original list and tree code), Mark van Doesburg (old OpenCASCADe face connection), Matt Gundry (Plot3d export), Matti Pellikka (cell complex and homology solver), Nicolas Tardieu (help with netgen integration), Pascale Noyret (MED mesh ID), Pierre Badel (root finding and minimization), Ruth Sabariego (pyramids), Stephen Guzik (old CGNS ID, old partitioning code), Bastien Gorissen (parallel remote post-processing), Eric Bechet (sorver), Gilles Marcmann (camera and stereo mode, X3D export), Ashish Negi (Netgen CAD healing), Trevor Strickler (hybrid structured mesh coupling with pyramids), Amaury Johnen (Bezier code, high-order element validity), Benjamin Ruard (old Java wrappers), Maxime Graulich (iOS/Android port), Francois Henrotte (ONELAB metamodels), Sebastian Eiser (PGF export), Alexis Salzman (compressed ID), Hang Si (TetGen/BR boundary recovery code), Fernando Lorenzo (Tochnog export), Larry Price (Gambit export), Anthony Royer (new partitioning code, MSH4 ID), Darcy Beurle (code cleanup and performance improvements), Zhidong Han (LSDENA export); Ismail Badia (hierarchical basis functions); Jeremy Theler (X3D export); Thomas Toulorge (high order mesh optimizer, new CGNS IO); Max Orok (binary PLY). See comments in the sources for more information. If we forgot to list your contributions please send us an email!

Thanks to the following folks who have contributed by providing fresh ideas on theoretical or programming topics, who have sent patches, requests for changes or improvements, or who gave us access to exotic machines for testing Gmsh: Juan Abanto, Olivier Adam, Guillaume Alleon, Laurent Champaney, Pascal Dupuis, Patrick Dular, Philippe Geuzaine, Johan Gyselinck, Francois Henriotte, Benoit Meys, Nicolas Moe, Osamu Nakamura, Chad Schmutzer, Jean-Luc Fl'ejou, Xavier Dardenne, Christophe Prud'homme, Sebastien Clerc, Jose Miguel Pasini, Philippe Lussou, Jacques Kools, Bayram Yenikaya, Peter Hornby, Krishna Mohan Gundu, Christopher Stott, Timmy Schumacher, Carl Osterwisch, Bruno Frackowiak, Philip Kelleners, Romuald Conty, Renaud Sizaire, Michel Benhamou, Tom De Vuyst, Kris Van den Abeele, Simon Vun, Simon Corbin, Thomas De-Soza, Marcus Drosson, Antoine Dechaume, Jose Paulo Moitinho de Almeida, Thomas Pinchard, Corrado Chisari, Axel Hackbarth, Peter Wainwright, Jiri Hnidek, Thierry Thomas, Konstantinos Poulios, Laurent Van Miegroet, Shahrrokh Ghavamian, Geordie McBain, Jose Paulo Moitinho de Almeida, Guillaume Demesy, Wendy Merks-Soolfs, Cosmin Stefan Deaconu, Nigel Nunn, Serban Georgescu, Julien Troufflard, Michele Mocciola, Matthijs Sypkens Smit, Sauli Ruuska, Romain Boman, Fredrik Ekre, Mark Burton, Max Orok, Paul Cristini, Isuru Fernando, Jose Paulo Moitinho de Almeida, Sophie Le Bras, Alberto Escrig, Samy Mukadi, Peter Johnston, Bruno de Sousa Alves, Stefan Bruens.

Special thanks to Bill Spitzak, Michael Sweet, Matthias Melcher, Greg Ercolano
and others for the Fast Light Tool Kit on which Gmsh’s GUI is based. See http://www.fltk.org for more info on this excellent object-oriented, cross-platform toolkit. Special thanks also to EDF for funding the original OpenCASCADE and MED integration in 2006-2007.

The TetGen/BR code (Mesh/tetgenBR.{cpp,h}) is copyright (c) 2016 Hang Si, Weierstrass Institute for Applied Analysis and Stochastics. It is relicensed under the terms of LICENSE.txt for use in Gmsh thanks to a Software License Agreement between Weierstrass Institute for Applied Analysis and Stochastics and GMESH SPRL.

The AVL tree code (Common/avl.{cpp,h}) and the YUV image code (Graphics/gl2yuv.{cpp,h}) are copyright (C) 1988-1993, 1995 The Regents of the University of California. Permission to use, copy, modify, and distribute this software and its documentation for any purpose and without fee is hereby granted, provided that the above copyright notice appear in all copies and that both that copyright notice and this permission notice appear in supporting documentation, and that the name of the University of California not be used in advertising or publicity pertaining to distribution of the software without specific, written prior permission. The University of California makes no representations about the suitability of this software for any purpose. It is provided "as is" without express or implied warranty.

The picojson code (Common/picojson.h) is Copyright 2009-2010 Cybozu Labs, Inc., Copyright 2011-2014 Kazuho Oku, All rights reserved. Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met: 1. Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer. 2. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution. THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

The nanoflann code (Numeric/nanoflann.hpp) is Copyright 2008-2009 Marius Muja, 2008-2009 David G. Lowe, 2011-2016 Jose Luis Blanco. Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met: 1. Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer. 2. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution. THIS SOFTWARE IS PROVIDED BY THE AUTHOR ‘‘AS IS’’ AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE AUTHOR BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING
IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY
OF SUCH DAMAGE.

The trackball code (Graphics/Trackball.{cpp.h}) is copyright (C) 1993, 1994, Silicon
Graphics, Inc. ALL RIGHTS RESERVED. Permission to use, copy, modify, and

distribute this software for any purpose and without fee is hereby granted,
provided that the above copyright notice appear in all copies and that both the

copyright notice and this permission notice appear in supporting documentation,
and that the name of Silicon Graphics, Inc. not be used in advertising or

publicity pertaining to distribution of the software without specific, written

prior permission.

The GIF and PPM routines (Graphics/gl2gif.cpp) are based on code copyright (C)
1989, 1991, Jef Poskanzer. Permission to use, copy, modify, and distribute this
software and its documentation for any purpose and without fee is hereby

graded, provided that the above copyright notice appear in all copies and that
both that copyright notice and this permission notice appear in supporting
documentation. This software is provided "as is" without express or implied

warranty.

The colorbar widget (Fltk/colorbarWindow.cpp) was inspired by code from the
Vis5d program for visualizing five dimensional gridded data sets, copyright (C)

In addition, this version of Gmsh may contain the following contributed,
optional codes in the contrib/ directory, each governed by their own license:

* contrib/ANN copyright (C) 1997-2005 University of Maryland and Sunil Arya and
David Mount;

* contrib/gmm copyright (C) 2002-2008 Yves Renard;

* contrib/hxt - Copyright (C) 2017-2018 - Universite catholique de Louvain;

* contrib/kbipack copyright (C) 2005 Saku Suuriniemi;

* contrib/MathEx based in part on the work of the SSCILIB Library, copyright (C)
2000-2003 Sadao Massago;

* contrib/metis written by George Karypis (karypis at cs.umn.edu), copyright (C)
1995-2013 Regents of the University of Minnesota;

* contrib/mpeg_encode copyright (c) 1995 The Regents of the University of
California;

* contrib/Netgen copyright (C) 1994-2004 Joachim Sch"oberl;

* contrib/bamg from Freefem++ copyright (C) Frederic Hecht;

* contrib/ALGLIB (C) Sergey Bochkanov (ALGLIB project);

* contrib/mmg3d from MMG3D Version 4.0 (C) 2004-2011 Cecile Dobrzynski and
Pascal Frey (IPB - UPMC - INRIA);

* contrib/blossom copyright (C) 1995-1997 Bill Cook et al.;

* contrib/bamg from Freefem++ copyright (C) Frederic Hecht;
* contrib/voro++ from Voro++ Copyright (c) 2008, The Regents of the University of California, through Lawrence Berkeley National Laboratory (subject to receipt of any required approvals from the U.S. Dept. of Energy). All rights reserved;

* contrib/zipper from MiniZip - Copyright (c) 1998-2010 - by Gilles Vollant - version 1.1 64 bits from Mathias Svensson.

heck the configuration options to see which have been enabled.
Appendix I License

Gmsh is provided under the terms of the GNU General Public License (GPL), Version 2 or later, with the following exception:

The copyright holders of Gmsh give you permission to combine Gmsh with code included in the standard release of Netgen (from Joachim Sch"oberl), METIS (from George Karypis at the University of Minnesota), OpenCASCADE (from Open CASCADE S.A.S) and ParaView (from Kitware, Inc.) under their respective licenses. You may copy and distribute such a system following the terms of the GNU GPL for Gmsh and the licenses of the other code concerned, provided that you include the source code of that other code when and as the GNU GPL requires distribution of source code.

Note that people who make modified versions of Gmsh are not obliged to grant this special exception for their modified versions; it is their choice whether to do so. The GNU General Public License gives permission to release a modified version without this exception; this exception also makes it possible to release a modified version which carries forward this exception.

End of exception.

GNU GENERAL PUBLIC LICENSE
Version 2, June 1991

Copyright (C) 1989, 1991 Free Software Foundation, Inc.
51 Franklin St, Fifth Floor, Boston, MA 02110-1301 USA
Everyone is permitted to copy and distribute verbatim copies of this license document, but changing it is not allowed.

Preamble

The licenses for most software are designed to take away your freedom to share and change it. By contrast, the GNU General Public License is intended to guarantee your freedom to share and change free software--to make sure the software is free for all its users. This General Public License applies to most of the Free Software Foundation's software and to any other program whose authors commit to using it. (Some other Free Software Foundation software is covered by the GNU Library General Public License instead.) You can apply it to your programs, too.

When we speak of free software, we are referring to freedom, not price. Our General Public Licenses are designed to make sure that you have the freedom to distribute copies of free software (and charge for this service if you wish), that you receive source code or can get it if you want it, that you can change the software or use pieces of it in new free programs; and that you know you can do these things.

To protect your rights, we need to make restrictions that forbid anyone to deny you these rights or to ask you to surrender the rights. These restrictions translate to certain responsibilities for you if you distribute copies of the software, or if you modify it.

For example, if you distribute copies of such a program, whether gratis or for a fee, you must give the recipients all the rights that you have. You must make sure that they, too, receive or can get the
source code. And you must show them these terms so they know their rights.

We protect your rights with two steps: (1) copyright the software, and (2) offer you this license which gives you legal permission to copy, distribute and/or modify the software.

Also, for each author’s protection and ours, we want to make certain that everyone understands that there is no warranty for this free software. If the software is modified by someone else and passed on, we want its recipients to know that what they have is not the original, so that any problems introduced by others will not reflect on the original authors’ reputations.

Finally, any free program is threatened constantly by software patents. We wish to avoid the danger that redistributors of a free program will individually obtain patent licenses, in effect making the program proprietary. To prevent this, we have made it clear that any patent must be licensed for everyone’s free use or not licensed at all.

The precise terms and conditions for copying, distribution and modification follow.

GNU GENERAL PUBLIC LICENSE
TERMS AND CONDITIONS FOR COPYING, DISTRIBUTION AND MODIFICATION

0. This License applies to any program or other work which contains a notice placed by the copyright holder saying it may be distributed under the terms of this General Public License. The “Program”, below, refers to any such program or work, and a “work based on the Program” means either the Program or any derivative work under copyright law: that is to say, a work containing the Program or a portion of it, either verbatim or with modifications and/or translated into another language. (Hereinafter, translation is included without limitation in the term “modification”.) Each licensee is addressed as “you”.

Activities other than copying, distribution and modification are not covered by this License; they are outside its scope. The act of running the Program is not restricted, and the output from the Program is covered only if its contents constitute a work based on the Program (independent of having been made by running the Program). Whether that is true depends on what the Program does.

1. You may copy and distribute verbatim copies of the Program’s source code as you receive it, in any medium, provided that you conspicuously and appropriately publish on each copy an appropriate copyright notice and disclaimer of warranty; keep intact all the notices that refer to this License and to the absence of any warranty; and give any other recipients of the Program a copy of this License along with the Program.

You may charge a fee for the physical act of transferring a copy, and you may at your option offer warranty protection in exchange for a fee.

2. You may modify your copy or copies of the Program or any portion of it, thus forming a work based on the Program, and copy and distribute such modifications or work under the terms of Section 1 above, provided that you also meet all of these conditions:
a) You must cause the modified files to carry prominent notices
stating that you changed the files and the date of any change.

b) You must cause any work that you distribute or publish, that in
whole or in part contains or is derived from the Program or any
part thereof, to be licensed as a whole at no charge to all third
parties under the terms of this License.

c) If the modified program normally reads commands interactively
when run, you must cause it, when started running for such
interactive use in the most ordinary way, to print or display an
announcement including an appropriate copyright notice and a
notice that there is no warranty (or else, saying that you provide
a warranty) and that users may redistribute the program under
these conditions, and telling the user how to view a copy of this
License. (Exception: if the Program itself is interactive but
does not normally print such an announcement, your work based on
the Program is not required to print an announcement.)

These requirements apply to the modified work as a whole. If
identifiable sections of that work are not derived from the Program,
and can be reasonably considered independent and separate works in
themselves, then this License, and its terms, do not apply to those
sections when you distribute them as separate works. But when you
distribute the same sections as part of a whole which is a work based
on the Program, the distribution of the whole must be on the terms of
this License, whose permissions for other licensees extend to the
entire whole, and thus to each and every part regardless of who wrote it.

Thus, it is not the intent of this section to claim rights or contest
your rights to work written entirely by you; rather, the intent is to
exercise the right to control the distribution of derivative or
collective works based on the Program.

In addition, mere aggregation of another work not based on the Program
with the Program (or with a work based on the Program) on a volume of
a storage or distribution medium does not bring the other work under
the scope of this License.

3. You may copy and distribute the Program (or a work based on it,
under Section 2) in object code or executable form under the terms of
Sections 1 and 2 above provided that you also do one of the following:

a) Accompany it with the complete corresponding machine-readable
source code, which must be distributed under the terms of Sections
1 and 2 above on a medium customarily used for software interchange; or,

b) Accompany it with a written offer, valid for at least three
years, to give any third party, for a charge no more than your
cost of physically performing source distribution, a complete
machine-readable copy of the corresponding source code, to be
distributed under the terms of Sections 1 and 2 above on a medium
customarily used for software interchange; or,

c) Accompany it with the information you received as to the offer
to distribute corresponding source code. (This alternative is
allowed only for noncommercial distribution and only if you
The source code for a work means the preferred form of the work for making modifications to it. For an executable work, complete source code means all the source code for all modules it contains, plus any associated interface definition files, plus the scripts used to control compilation and installation of the executable. However, as a special exception, the source code distributed need not include anything that is normally distributed (in either source or binary form) with the major components (compiler, kernel, and so on) of the operating system on which the executable runs, unless that component itself accompanies the executable.

If distribution of executable or object code is made by offering access to copy from a designated place, then offering equivalent access to copy the source code from the same place counts as distribution of the source code, even though third parties are not compelled to copy the source along with the object code.

4. You may not copy, modify, sublicense, or distribute the Program except as expressly provided under this License. Any attempt otherwise to copy, modify, sublicense or distribute the Program is void, and will automatically terminate your rights under this License. However, parties who have received copies, or rights, from you under this License will not have their licenses terminated so long as such parties remain in full compliance.

5. You are not required to accept this License, since you have not signed it. However, nothing else grants you permission to modify or distribute the Program or its derivative works. These actions are prohibited by law if you do not accept this License. Therefore, by modifying or distributing the Program (or any work based on the Program), you indicate your acceptance of this License to do so, and all its terms and conditions for copying, distributing or modifying the Program or works based on it.

6. Each time you redistribute the Program (or any work based on the Program), the recipient automatically receives a license from the original licensor to copy, distribute or modify the Program subject to these terms and conditions. You may not impose any further restrictions on the recipients’ exercise of the rights granted herein. You are not responsible for enforcing compliance by third parties to this License.

7. If, as a consequence of a court judgment or allegation of patent infringement or for any other reason (not limited to patent issues), conditions are imposed on you (whether by court order, agreement or otherwise) that contradict the conditions of this License, they do not excuse you from the conditions of this License. If you cannot distribute so as to satisfy simultaneously your obligations under this License and any other pertinent obligations, then as a consequence you may not distribute the Program at all. For example, if a patent license would not permit royalty-free redistribution of the Program by all those who receive copies directly or indirectly through you, then the only way you could satisfy both it and this License would be to refrain entirely from distribution of the Program.
If any portion of this section is held invalid or unenforceable under any particular circumstance, the balance of the section is intended to apply and the section as a whole is intended to apply in other circumstances.

It is not the purpose of this section to induce you to infringe any patents or other property right claims or to contest validity of any such claims; this section has the sole purpose of protecting the integrity of the free software distribution system, which is implemented by public license practices. Many people have made generous contributions to the wide range of software distributed through that system in reliance on consistent application of that system; it is up to the author/donor to decide if he or she is willing to distribute software through any other system and a licensee cannot impose that choice.

This section is intended to make thoroughly clear what is believed to be a consequence of the rest of this License.

8. If the distribution and/or use of the Program is restricted in certain countries either by patents or by copyrighted interfaces, the original copyright holder who places the Program under this License may add an explicit geographical distribution limitation excluding those countries, so that distribution is permitted only in or among countries not thus excluded. In such case, this License incorporates the limitation as if written in the body of this License.

9. The Free Software Foundation may publish revised and/or new versions of the General Public License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns.

Each version is given a distinguishing version number. If the Program specifies a version number of this License which applies to it and "any later version", you have the option of following the terms and conditions either of that version or of any later version published by the Free Software Foundation. If the Program does not specify a version number of this License, you may choose any version ever published by the Free Software Foundation.

10. If you wish to incorporate parts of the Program into other free programs whose distribution conditions are different, write to the author to ask for permission. For software which is copyrighted by the Free Software Foundation, write to the Free Software Foundation; we sometimes make exceptions for this. Our decision will be guided by the two goals of preserving the free status of all derivatives of our free software and of promoting the sharing and reuse of software generally.

NO WARRANTY

11. BECAUSE THE PROGRAM IS LICENSED FREE OF CHARGE, THERE IS NO WARRANTY FOR THE PROGRAM, TO THE EXTENT PERMITTED BY APPLICABLE LAW. EXCEPT WHEN OTHERWISE STATED IN WRITING THE COPYRIGHT HOLDERS AND/OR OTHER PARTIES PROVIDE THE PROGRAM "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THE ENTIRE RISK AS TO THE QUALITY AND PERFORMANCE OF THE PROGRAM IS WITH YOU. SHOULD THE PROGRAM PROVE DEFECTIVE, YOU ASSUME THE COST OF ALL NECESSARY SERVICING,
REPAIR OR CORRECTION.

12. IN NO EVENT UNLESS REQUIRED BY APPLICABLE LAW OR AGREED TO IN WRITING
WILL ANY COPYRIGHT HOLDER, OR ANY OTHER PARTY WHO MAY MODIFY AND/OR
REDISTRIBUTE THE PROGRAM AS PERMITTED ABOVE, BE LIABLE TO YOU FOR DAMAGES,
INCLUDING ANY GENERAL, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING
OUT OF THE USE OR INABILITY TO USE THE PROGRAM (INCLUDING BUT NOT LIMITED
TO LOSS OF DATA OR DATA BEING RENDERED INACCURATE OR LOSSES SUSTAINED BY
YOU OR THIRD PARTIES OR A FAILURE OF THE PROGRAM TO OPERATE WITH ANY OTHER
PROGRAMS), EVEN IF SUCH HOLDER OR OTHER PARTY HAS BEEN ADVISED OF THE
POSSIBILITY OF SUCH DAMAGES.

END OF TERMS AND CONDITIONS

How to Apply These Terms to Your New Programs

If you develop a new program, and you want it to be of the greatest
possible use to the public, the best way to achieve this is to make it
free software which everyone can redistribute and change under these terms.

To do so, attach the following notices to the program. It is safest
to attach them to the start of each source file to most effectively
convey the exclusion of warranty; and each file should have at least
the "copyright" line and a pointer to where the full notice is found.

<one line to give the program's name and a brief idea of what it does.>
Copyright (C) <year> <name of author>

This program is free software; you can redistribute it and/or modify
it under the terms of the GNU General Public License as published by
the Free Software Foundation; either version 2 of the License, or
(at your option) any later version.

This program is distributed in the hope that it will be useful,
but WITHOUT ANY WARRANTY; without even the implied warranty of
MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the
GNU General Public License for more details.

You should have received a copy of the GNU General Public License
along with this program; if not, write to the Free Software
Foundation, Inc., 59 Temple Place, Suite 330, Boston, MA 02111-1307 USA

Also add information on how to contact you by electronic and paper mail.

If the program is interactive, make it output a short notice like this
when it starts in an interactive mode:

Gnomovision version 69, Copyright (C) <year> name of author
Gnomovision comes with ABSOLUTELY NO WARRANTY; for details type 'show w'.
This is free software, and you are welcome to redistribute it
under certain conditions; type 'show c' for details.

The hypothetical commands 'show w' and 'show c' should show the appropriate
parts of the General Public License. Of course, the commands you use may
be called something other than 'show w' and 'show c'; they could even be
mouse-clicks or menu items--whatever suits your program.
You should also get your employer (if you work as a programmer) or your school, if any, to sign a "copyright disclaimer" for the program, if necessary. Here is a sample; alter the names:

Yoyodyne, Inc., hereby disclaims all copyright interest in the program 'Gnomovision' (which makes passes at compilers) written by James Hacker.

<signature of Ty Coon>, 1 April 1989
Ty Coon, President of Vice

This General Public License does not permit incorporating your program into proprietary programs. If your program is a subroutine library, you may consider it more useful to permit linking proprietary applications with the library. If this is what you want to do, use the GNU Library General Public License instead of this License.
# Concept index

## 2
- 2D plots ........................................ 77

## 3
- 3D plots ........................................ 77

## A
- Acknowledgments ................................ 329
- API ............................................. 249
- Authors, e-mail ................................ 8

## B
- Background mesh ................................ 49
- Binary operators ................................ 25
- Bindings, keyboard ................................ 17
- Bindings, mouse .................................. 16
- Boolean operations, geometry .................. 43
- Bugs, reporting .................................. 8

## C
- Changelog ........................................ 313
- Characteristic lengths ......................... 49
- Colors ............................................ 25
- Command-line options ......................... 12
- Commands, general .............................. 30
- Commands, geometry ............................ 37
- Commands, mesh ................................ 49
- Commands, post-processing .................... 78
- Comments ........................................ 21
- Concepts, index ................................ 341
- Conditionals ..................................... 29
- Constants ........................................ 21
- Contact information ............................. 8
- Contributors, list ................................ 329
- Copyright ........................................ 3, 329
- Credits .......................................... 329
- Curves, elementary .............................. 38
- Curves, physical ................................ 38

## D
- Developer, information ......................... 303
- Document syntax ................................ 9
- Download ........................................ 1

## E
- E-mail, authors .................................. 8
- Elementary curves .............................. 38

Elementary points ................................ 37
Elementary surfaces .............................. 39
Elementary volumes .............................. 40
Evaluation order .................................. 26
Examples .......................................... 135
Expressions, affectation ......................... 30
Expressions, character ........................... 24
Expressions, color ................................ 25
Expressions, definition ........................... 21
Expressions, floating point ....................... 21
Expressions, identifiers ......................... 30
Expressions, lists ................................ 22
Extrusion, geometry .............................. 42
Extrusion, mesh .................................... 67

## F
- FAQ ................................................ 305
- File format, mesh ............................... 111
- File formats ...................................... 111
- File, comments ................................... 21
- Floating point numbers ........................... 21
- Frequently asked questions .................... 305
- Functions, built-in ............................... 27

## G
- General commands ............................... 30
- Geometry commands ............................. 37
- Geometry, boolean operations .................. 43
- Geometry, difference ............................ 43
- Geometry, extrusion ............................. 42
- Geometry, fragments ............................ 43
- Geometry, intersection ......................... 43
- Geometry, module ............................... 37
- Geometry, options ............................... 46
- Geometry, transformations ...................... 44
- Geometry, union ................................ 43
- Graphs .......................................... 77

## H
- History, versions ............................... 313

## I
- Index, concepts ................................ 341
- Index, syntax ................................... 343
- Interactive mode ................................. 11
- Internet address ................................. 1
- Introduction .................................... 5
<table>
<thead>
<tr>
<th>K</th>
<th>342</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keyboard, shortcuts</td>
<td>17</td>
</tr>
<tr>
<td>Keywords, index</td>
<td>343</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>3</td>
</tr>
<tr>
<td>License</td>
<td>333</td>
</tr>
<tr>
<td>Lines</td>
<td>38</td>
</tr>
<tr>
<td>Loops</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>28</td>
</tr>
<tr>
<td>Macros, user-defined</td>
<td></td>
</tr>
<tr>
<td>Mailing list</td>
<td>8</td>
</tr>
<tr>
<td>Mesh commands</td>
<td>49</td>
</tr>
<tr>
<td>Mesh, background</td>
<td>49</td>
</tr>
<tr>
<td>Mesh, element size</td>
<td>49</td>
</tr>
<tr>
<td>Mesh, extrusion</td>
<td>67</td>
</tr>
<tr>
<td>Mesh, file format</td>
<td>111</td>
</tr>
<tr>
<td>Mesh, module</td>
<td>47</td>
</tr>
<tr>
<td>Mesh, options</td>
<td>74</td>
</tr>
<tr>
<td>Mesh, transfinite</td>
<td>67</td>
</tr>
<tr>
<td>Module, geometry</td>
<td>37</td>
</tr>
<tr>
<td>Module, Mesh</td>
<td>47</td>
</tr>
<tr>
<td>Module, Post-processing</td>
<td>77</td>
</tr>
<tr>
<td>Module, Solver</td>
<td>75</td>
</tr>
<tr>
<td>Mouse, actions</td>
<td>16</td>
</tr>
<tr>
<td>MSH4 file</td>
<td>111</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>119</td>
</tr>
<tr>
<td>Nodes, ordering</td>
<td></td>
</tr>
<tr>
<td>Non-interactive mode</td>
<td>12</td>
</tr>
<tr>
<td>Numbers, real</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>11</td>
</tr>
<tr>
<td>Operating system</td>
<td></td>
</tr>
<tr>
<td>Operator precedence</td>
<td>26</td>
</tr>
<tr>
<td>Operators, definition</td>
<td>25</td>
</tr>
<tr>
<td>Options, command-line</td>
<td>12</td>
</tr>
<tr>
<td>Options, geometry</td>
<td>46</td>
</tr>
<tr>
<td>Options, mesh</td>
<td>74</td>
</tr>
<tr>
<td>Options, post-processing</td>
<td>110</td>
</tr>
<tr>
<td>Order, evaluation</td>
<td>26</td>
</tr>
<tr>
<td>Overview</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>38</td>
</tr>
<tr>
<td>Physical curves</td>
<td></td>
</tr>
<tr>
<td>Physical points</td>
<td>37</td>
</tr>
<tr>
<td>Physical surfaces</td>
<td>39</td>
</tr>
<tr>
<td>Physical volumes</td>
<td>40</td>
</tr>
<tr>
<td>Plots</td>
<td>77</td>
</tr>
<tr>
<td>Plugins, post-processing</td>
<td>82</td>
</tr>
<tr>
<td>Points, elementary</td>
<td>37</td>
</tr>
<tr>
<td>Points, physical</td>
<td>37</td>
</tr>
<tr>
<td>Post-processing commands</td>
<td>78</td>
</tr>
<tr>
<td>Post-processing plugins</td>
<td>82</td>
</tr>
<tr>
<td>Post-processing, module</td>
<td>77</td>
</tr>
<tr>
<td>Post-processing, options</td>
<td>110</td>
</tr>
<tr>
<td>Precedence, operators</td>
<td>26</td>
</tr>
<tr>
<td>Programming, API</td>
<td>249</td>
</tr>
<tr>
<td>Programming, notes</td>
<td>303</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>305</td>
</tr>
<tr>
<td>Questions, frequently asked</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>21</td>
</tr>
<tr>
<td>Real numbers</td>
<td></td>
</tr>
<tr>
<td>Reporting bugs</td>
<td>8</td>
</tr>
<tr>
<td>Rotation</td>
<td>44</td>
</tr>
<tr>
<td>Rules, syntactic</td>
<td>9</td>
</tr>
<tr>
<td>Running Gmsh</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>44</td>
</tr>
<tr>
<td>Scale</td>
<td></td>
</tr>
<tr>
<td>Shortcuts, keyboard</td>
<td>17</td>
</tr>
<tr>
<td>Size, elements</td>
<td>49</td>
</tr>
<tr>
<td>Solver, module</td>
<td>75</td>
</tr>
<tr>
<td>Strings</td>
<td>24</td>
</tr>
<tr>
<td>Surfaces, elementary</td>
<td>39</td>
</tr>
<tr>
<td>Surfaces, physical</td>
<td>39</td>
</tr>
<tr>
<td>Symmetry</td>
<td>44</td>
</tr>
<tr>
<td>Syntax, index</td>
<td>343</td>
</tr>
<tr>
<td>Syntax, rules</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>25</td>
</tr>
<tr>
<td>Ternary operators</td>
<td></td>
</tr>
<tr>
<td>Transfinite, mesh</td>
<td>67</td>
</tr>
<tr>
<td>Transformations, geometry</td>
<td>44</td>
</tr>
<tr>
<td>Translation</td>
<td>44</td>
</tr>
<tr>
<td>Tutorial</td>
<td>135</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>25</td>
</tr>
<tr>
<td>Unary operators</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>313</td>
</tr>
<tr>
<td>Versions</td>
<td></td>
</tr>
<tr>
<td>Views</td>
<td>77</td>
</tr>
<tr>
<td>Volumes, elementary</td>
<td>40</td>
</tr>
<tr>
<td>Volumes, physical</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>1</td>
</tr>
<tr>
<td>Web site</td>
<td></td>
</tr>
</tbody>
</table>
Syntax index

! .................................................. 26
!.................................................. 26
\%  .................................................. 26
\% .................................................. 26
& .................................................. 26
&& .................................................. 26
( .................................................. 26
() .................................................. 26
* .................................................. 26
* .................................................. 30
+ .................................................. 26
++ .................................................. 26
+= .................................................. 30
- .................................................. 26
-, --, -parse_and_exit .............................. 15
-= .................................................. 26
0 .................................................. 30
-1, -2, -3 ......................................... 12
-a, -g, -n, -s, -p .................................. 12
-algo string........................................ 13
-aniso_max_value .................................. 14
-barycentric_refine ................................ 13
-bg file ............................................ 15
-bin ............................................... 13
-camera .......................................... 15
-check ............................................ 14
-clcurv value ..................................... 14
-clmax value ...................................... 14
-clmin value ...................................... 14
-clscale value .................................... 14
-combine ......................................... 14
-convert files ................................... 14
-cpu ............................................... 16
-display string ................................... 15
-epsclcid value ................................... 14
-fontsize int ..................................... 15
-format string ..................................... 13
-gamepad .......................................... 15
-help .............................................. 16
-help_options ..................................... 16
-ho_[min,max,nlayers] ............................. 14
-ignore_periodicity ................................ 14
-info ............................................. 16
-link int ......................................... 14
-listen .......................................... 15
-log filename ..................................... 15
-match ........................................... 12
-merge .......................................... 15
-minterpreter string .............................. 15
-n .................................................. 15
-new .............................................. 15
-nodb ............................................ 15
-nopopup .......................................... 15
-nt int .......................................... 16
-nmsubedges ...................................... 15
-o file ........................................... 12
-open ............................................. 15
-optimize[.netgen] ................................ 14
-optimize_ho ...................................... 14
-optimize_threshold ................................ 14
-option file ...................................... 16
-order int ....................................... 14
-part int ........................................ 13
-part_[no]_ghosts .................................. 13
-part_[no]_physicals .............................. 13
-part_[no]_topo ................................... 13
-part_split ....................................... 13
-part_to[no]_pro .................................. 13
-part_weight tri|quad|tet|hex|pri|pyr|trih int ..................................... 13
-pid .............................................. 15
-preserve_numbering_msh2 ......................... 13
-pyinterpreter string ............................. 15
-rand value ...................................... 14
-reclassify angle .................................. 13
-refine ........................................... 13
-reparam angle ................................... 13
-run .............................................. 15
-save ............................................. 12
-save_all ........................................ 13
-save_parametric .................................. 13
-save_topology .................................... 13
-setnumber name value ............................ 16
-setstring name value ............................. 16
-smooth int ...................................... 13
-smooth_ratio value .............................. 14
-stereo .......................................... 15
-string "string" ................................... 16
-swappangle value ................................ 14
-theme string ..................................... 15

-tol value .......................... 12
-v int ................................ 15
-version ............................. 16
-watch pattern ..................... 15

/
/. ................................ 26
/*/ ................................ 21
// ................................ 21
/=................................ 30

:
:.................................. 26

<
< ................................ 26
<Recursive> Color color-expression {  
<Physical> Point | Curve | Surface |  
Volume { expression-list-or-all }; ... }
...................................... 72
<Recursive> Delete { <Physical> Point |  
Curve | Surface | Volume {  
expression-list-or-all }; ... } ...... 46
<Recursive> Hide { <Physical> Point | Curve |  
Surface | Volume { expression-list-or-all  
}; ... } ............................. 46, 72
<Recursive> Show { <Physical> Point | Curve |  
Surface | Volume { expression-list-or-all  
}; ... } ............................. 46, 73
<=.................................. 26

=
=................................. 30
==............................... 26

>
>................................. 26
>................................. 26

?
?................................. 26

^   ................................ 26
^-.................................. 26

|   ................................ 26
||.................................. 26

A
Abort; ............................. 32
Acos ( expression ) .................. 27
AdaptMesh { expression-list } {  
expression-list } { { expression-list < ,  
... > } } ............................. 70
Affine { expression-list } { transform-list }
..................................... 45
Alias View[expression]; ............... 78
AliasWithOptions View[expression]; .... 78
Asin ( expression ) .................. 27
Atan ( expression ) .................. 27
Atan2 ( expression, expression ) ...... 27
Attractor .......................... 51
AttractorAnisoCurve ................. 51
AutomaticMeshSizeField ............. 52

B
Background Field = expression; ........ 51
Background Mesh View[expression]; .... 79
Ball ................................ 53
Bezier ( expression ) = { expression-list };
.................................. 38
boolean .......................... 43
BooleanDifference { boolean-list } {  
boolean-list } ...................... 43, 44
BooleanFragments { boolean-list } {  
boolean-list } ...................... 43
BooleanIntersection ( expression ) = {  
boolean-list } { boolean-list }; ...... 44
BooleanIntersection { boolean-list } {  
boolean-list } ...................... 43
BooleanUnion { boolean-list } { boolean-list }  
.................................. 43, 44
Boundary { transform-list } .......... 45
BoundaryLayer ..................... 54
BoundingBox { expression, expression,  
expression, expression, expression,  
expression } ........................ 33
BoundingBox ........................ 33
Box ................................ 55
Box ( expression ) = { expression-list }; .. 41
BSpline ( expression ) = { expression-list };
.................................. 38
build-in-function ............................. 27

C
Call string | char-expression ; .......... 28
Ceil ( expression ) .................. 27
Chamfer { expression-list } { expression-list  
} { expression-list } { expression-list }  
.................................. 43
char-option = char-expression .......... 32
Characteristic Length { expression-list } =  
expression; ........................ 50
Circle ( expression ) = { expression, expression, expression <, ... >}; ........ 38
ClassifySurfaces { expression, expression , expression <, expression >};........... 72
Coherence Mesh;.............................. 72
Coherence;.................................. 45
Cohomology ( { expression-list } ) { { expression-list }, expression-list } );............... 74
color-option = color-expression;........... 32
Combine ElementsByViewName;............. 78
Combine ElementsFromAllViews | Combine Views; ........................................ 78
Combine ElementsFromVisibleViews;........ 78
Combine TimeStepsByViewName | Combine TimeSteps;.................................... 78
Combine TimeStepsFromAllViews;............ 78
Combine TimeStepsFromVisibleViews;........ 78
CombinedBoundary { transform-list }........... 45
Compound Curve | Surface { expression-list-or-all } ];........... 73
Compound Spline | BSpline ( expression ) = { expression-list } Using expression;........... 39
Cone ( expression ) = { expression-list };........................................ 41
CopyOptions View[expression, expression];................................. 78
Cos ( expression ).......................... 27
Cosh ( expression ).......................... 27
Cpu........................................... 30
CreateDir char-expression;.................. 32
CreateGeometry;............................ 72
CreateTopology;............................ 72
Curvature.................................. 56
Curve Loop ( expression ) = { expression-list };........................................ 39
Cylinder.................................. 56
Cylinder ( expression ) = { expression-list };........................................ 41

D
DefineConstant[ string = { expression|char-expression, onelab-options } <, ... >];........ 32
DefineConstant[ string = expression|char-expression <, ... >];.......................... 32
Delete Embedded { <Physical> Point | Curve | Surface | Volume { expression-list-or-all } };... 46
Delete Empty Views;........................ 79
Delete Model;.............................. 33
Delete Options;............................ 34
Delete Physicals;......................... 34
Delete string;............................. 34
Delete Variables;......................... 34
Delete View[expression];.................. 79
Dilate { { expression-list }, { expression, expression, expression } } { transform-list }........ 44
Dilate { { expression-list }, expression } { transform-list }........ 44
Disk ( expression ) = { expression-list };........................................ 40
Distance.................................. 57
Draw;........................................ 33

E
Ellipse ( expression ) = { expression, expression, expression, <, ... >};........... 38
Else ........................................ 29
ElseIf ( expression )........................... 29
ENABLE_SM.................................. 243
ENABLE_ACIS................................. 243
ENABLE_ALGLIB.............................. 243
ENABLE_AN................. 243
ENABLE_BAM...................... 243
ENABLE_BLAS_LAPACK............... 243
ENABLE_BLOSSOM............... 243
ENABLE_BUILD_ANDROID.......... 243
ENABLE_BUILD_DYNAMIC.......... 243
ENABLE_BUILD_IOS................. 243
ENABLE_BUILD_LIB............... 243
ENABLE_BUILD_SHARED............ 243
ENABLE_C99...................... 244
ENABLE_CAIRO................. 244
ENABLE_CGNS..................... 243
ENABLE_CGNS_CPEX0045............. 244
ENABLE_CXX11.................... 244
ENABLE_DINTEGRATION.......... 244
ENABLE_DOMHEX.................... 244
ENABLE_Fltk...................... 244
ENABLE_GETDP..................... 244
ENABLE_GMM....................... 244
ENABLE_GMP....................... 244
ENABLE_GRAPHICS.............. 244
ENABLE_HX................. 244
ENABLE_KBIPACK.............. 244
ENABLE_MATHEX.............. 244
ENABLE_MED..................... 244
ENABLE_MSH..................... 244
ENABLE_METIS................. 244
ENABLE_MM3D................. 244
ENABLE_MPEG_ENCODE......... 245
ENABLE_MPI..................... 245
ENABLE_MSVC_STATIC_RUNTIME... 245
ENABLE_MUMPS.................. 245
ENABLE_NETGEN.................. 245
ENABLE_NUMPY.................. 245
ENABLE_OCC..................... 245
ENABLE_OCC_CAF.............. 245
ENABLE_OCC_STATIC.......... 245
ENABLE_OCC_TBB......... 245
ENABLE_ONELAB.............. 245
F

Fabs ( expression ) ................................. 27
Field[expression] = string; ......................... 50
Field[expression].string = char-expression | expression | expression-list; ........................ 50
Fillet ( expression-list ) { expression-list }
expression-list ................................. 42
Floor ( expression ) ................................. 28
Fmod ( expression, expression ) ..................... 27
For ( expression : expression ) .......................... 29
For ( expression : expression : expression ) ........ 29
For string In { expression : expression }
expression ................................ 29
For string In { expression : expression }...... 29
Frustum ........................................ 59

G

General.AlphaBlending ............................... 163
General.Antialiasing ................................. 163
General.ArrowHeadRadius ............................ 163
General.ArrowStemLength ............................ 163
General.ArrowStemRadius ............................ 163
General.Axes ....................................... 163
General.AxesAutoPosition ........................... 163
General.AxesForceValue ............................ 163
General.AxesFormatX ................................ 159
General.AxesFormatY ................................ 159
General.AxesFormatZ ................................ 159
General.AxesLabelX ................................ 159
General.AxesLabelY ................................ 159
General.AxesLabelZ ................................ 159
General.AxesMaxX .................................. 164
General.AxesMaxY .................................. 164
General.AxesMaxZ .................................. 164
General.AxesMinX .................................. 164
General.AxesMinY .................................. 164
General.AxesMinZ .................................. 164
General.AxesTicsX .................................. 164
General.AxesTicsY .................................. 164
General.AxesTicsZ .................................. 164
General.AxesValueMaxX ............................. 164
General.AxesValueMaxY ............................. 165
General.AxesValueMaxZ ............................. 165
General.AxesValueMinX ............................. 165
General.AxesValueMinY ............................. 165
General.AxesValueMinZ ............................. 165
General.BackgroundGradient ......................... 165
General.BackgroundImage3D ......................... 165
General.BackgroundImageFileName .................... 160
General.BackgroundImageHeight ....................... 166
General.BackgroundImagePage ......................... 165
General.BackgroundImagePositionX ..................... 165
General.BackgroundImagePositionY ..................... 165
General.BackgroundImageWidth ......................... 166
General.BoundingBoxSize .............................. 166
General.BuildInfo .............................. 160  General.ExtraHeight .......................... 170
General.CameraEyeSeparationRatio .............. 166  General.FastRedraw ........................... 171
General.CameraFocalLengthRatio ................. 166  General.FieldHeight ........................... 171
General.Clip0A .................................. 166  General.FieldPositionX ....................... 171
General.Clip0B .................................. 166  General.FieldPositionY ....................... 171
General.Clip0C .................................. 166  General.FileChooserPositionX ............... 171
General.Clip0D .................................. 167  General.FileChooserPositionY ............... 171
General.Clip1A .................................. 167  General.FileName .............................. 161
General.Clip1B .................................. 167  General.FltkColorScheme ..................... 171
General.Clip1C .................................. 167  General.FltkTheme ............................ 161
General.Clip1D .................................. 167  General.FontSize .............................. 171
General.Clip2A .................................. 167  General.FontSizeTitle ......................... 171
General.Clip3A .................................. 167  General.HighResolutionPointSizeFactor ..... 172
General.Clip3B .................................. 168  General.HighResolutionPointSizeFactor ..... 172
General.Clip3C .................................. 168  General.InitialModule ......................... 172
General.Clip4A .................................. 168  General.Light0 ................................ 173
General.Clip4B .................................. 168  General.Light0W ................................ 173
General.Clip4C .................................. 168  General.Light0X ................................ 173
General.Clip4D .................................. 168  General.Light0Y ................................ 173
General.Clip4E .................................. 168  General.Light0Z ................................ 173
General.Clip5A .................................. 168  General.Light1 ................................ 173
General.Clip5B .................................. 168  General.Light1W ................................ 174
General.Clip5C .................................. 168  General.Light1X ................................ 173
General.Clip5D .................................. 168  General.Light1Y ................................ 173
General.ClipFactor ................................ 169  General.Light1Z ................................ 173
General.ClipOnlyVolume ........................... 169  General.Light2W ................................ 174
General.ClipWholeElements ........................ 169  General.Light2Z ................................ 174
General.Color.Foreground ......................... 183  General.Light4 ................................ 175
General.ColorScheme ............................... 169  General.Light4Z ................................ 175
General.ConfirmOverwrite ......................... 169  General.Light5 ................................ 175
General.ContextPositionY ......................... 170  General.Light5X ................................ 175
General.DefaultFileName ......................... 160  General.Light5 ................................ 175
General.DetachedMenu ............................. 170  General.Light6 ................................ 175
General.Display .................................. 160  General.Light7 ................................ 175
General.DisplayBorderFactor ..................... 170  General.Light8 ................................ 175
General.DoubleBuffer ............................. 170  General.Light9 ................................ 175
General.DrawBoundingBoxes ....................... 170  General.Light10 ................................ 175
General.ErrorFileName ............................ 160  General.Light11 ................................ 175
General.ExecutableFileName ....................... 160  General.Light12 ................................ 175
General.ExpertMode ................................ 170  General.Light13 ................................ 175
| General.LightSY                      | 175 | General.ScaleY                      | 180 |
| General.LightSZ                      | 175 | General.ScaleZ                      | 180 |
| General.LineWidth                   | 176 | General.SessionFileName             | 162 |
| General.ManipulatorPositionX        | 176 | General.Shininess                   | 180 |
| General.ManipulatorPositionY        | 176 | General.ShininessExponent           | 180 |
| General.MaxX                        | 176 | General.ShowMessagesOnStartup       | 181 |
| General.MaxY                        | 176 | General.ShowModuleMenu              | 181 |
| General.MaxZ                        | 176 | General.ShowOptionsOnStartup        | 181 |
| General.MenuHeight                  | 176 | General.Sm1Axes                    | 181 |
| General.MenuPositionX               | 177 | General.Sm1AxesPositionX           | 181 |
| General.MenuPositionY               | 177 | General.Sm1AxesPositionY           | 181 |
| General.MenuWidth                   | 177 | General.Sm1AxesSize                | 181 |
| General.MessageFontSize             | 177 | General.StatsPosOrthographicY      | 181 |
| General.MessageHeight               | 177 | General.StatsPosOrthographicX      | 181 |
| General.MinX                        | 177 | General.Stereo                      | 181 |
| General.MinY                        | 177 | General.SystemMenuBar               | 182 |
| General.MinZ                        | 177 | General.Terminal                    | 182 |
| General.MouseHoverMesgests          | 177 | General.TextEditor                  | 162 |
| General.MouseInvertZoom             | 177 | General.TmpFileName                 | 162 |
| General.MouseSelection              | 177 | General.Tooltips                    | 182 |
| General.NativeFileChooser            | 177 | General.Trackball                   | 182 |
| General.NonModalWindows             | 178 | General.TrackballHyperbolicSheet    | 182 |
| General.NoPopup                     | 178 | General.TrackballQuaternion0        | 182 |
| General.NumThreads                  | 178 | General.TrackballQuaternion1        | 182 |
| General.OptionsFileName             | 161 | General.TrackballQuaternion2        | 182 |
| General.OptionsPositionX            | 178 | General.TrackballQuaternion3        | 182 |
| General_OptionsPositionX            | 178 | General.TranslationX                | 182 |
| General.OptionsPositionY            | 178 | General.TranslationY                | 183 |
| General.Orthographic                | 178 | General.TranslationZ                | 183 |
| General.PluginHeight                | 178 | General.TranslationZ                | 183 |
| General.PluginPositionX             | 178 | General.VectorType                  | 183 |
| General.PluginPositionY             | 178 | General.Verbosity                   | 183 |
| General.PluginWidth                 | 178 | General.Version                     | 162 |
| General.PointSize                   | 179 | General.VisibilityPositionX         | 183 |
| General.PolygonOffsetAlwaysOn       | 179 | General.VisibilityPositionY         | 183 |
| General.PolygonOffsetFactor         | 179 | General.WatchFilePattern            | 163 |
| General.PolygonOffsetUnits          | 179 | General.ZoomFactor                  | 183 |
| General.ProgressMeterStep           | 179 | Geometry.AutoCoherence              | 189 |
| General.QuadricSubdivisions         | 179 | Geometry.Clip                       | 190 |
| General.RecentFile0                 | 161 | Geometry.Color.HighlightOne         | 197 |
| General.RecentFile1                 | 161 | Geometry.Color.HighlightTwo         | 197 |
| General.RecentFile2                 | 161 | Geometry.Color.HighlightZero        | 197 |
| General.RecentFile3                 | 161 | Geometry.Color.Lines                | 197 |
| General.RecentFile5                 | 162 | Geometry.Color.Points               | 196 |
| General.RecentFile6                 | 162 | Geometry.Color.Projection           | 197 |
| General.RecentFile7                 | 162 | Geometry.Color.Selection            | 197 |
| General.RecentFile8                 | 162 | Geometry.Color.Surfaces             | 197 |
| General.RecentFile9                 | 162 | Geometry.Color.Tangents             | 197 |
| General.RotationCenterGravity       | 179 | Geometry.Color.Volumes              | 197 |
| General.RotationCenterX             | 180 | Geometry.CopyMeshingMethod          | 190 |
| General.RotationCenterY             | 180 | Geometry.DoubleClickedEntityTag     | 190 |
| General.RotationCenterZ             | 180 | Geometry.DoubleClickedLineCommand   | 189 |
| General.RotationX                   | 179 | Geometry.DoubleClickedPointCommand  | 189 |
| General.RotationY                   | 179 | Geometry.DoubleClickedSurfaceCommand| 189 |
| General.RotationZ                   | 179 | Geometry.DoubleClickedVolumeCommand | 189 |
| General.SaveOptions                 | 180 | Geometry.ExactExtrusion             | 190 |
| General.SaveSession                 | 180 | Geometry.ExtrudeReturnLateralEntities| 190 |
| General.ScaleX                      | 180 | Geometry.ExtrudeSplinePoints        | 190 |
| Geometry.HighlightOrphans    | 190 |
| Geometry.LabelType           | 190 |
| Geometry.Light               | 190 |
| Geometry.LightTwoSide        | 190 |
| Geometry.LineNumbers         | 191 |
| Geometry.Line                | 191 |
| Geometry.LineSelectWidth     | 191 |
| Geometry.LineType            | 191 |
| Geometry.LineWidth           | 191 |
| Geometry.MatchGeomAndMesh    | 191 |
| Geometry.MatchMeshScaleFactor| 191 |
| Geometry.MatchMeshTolerance  | 191 |
| GeometryNormals              | 191 |
| Geometry.NumSubEdges         | 191 |
| Geometry.OCCAutoFix          | 192 |
| Geometry.OCCBooleanPreserveNumbering | 192 |
| Geometry.OCCDisableSel       | 192 |
| Geometry.OCCFixDegenerated   | 192 |
| Geometry.OCCFixSmallEdges    | 192 |
| Geometry.OCCFixSmallFaces    | 192 |
| Geometry.OCCImportLabels     | 192 |
| Geometry.OCCMakeSolids       | 192 |
| Geometry.OCCParallel         | 192 |
| Geometry.OCCScaling          | 193 |
| Geometry.OCCSetFaces         | 193 |
| Geometry.OCTargetUnit        | 193 |
| Geometry.OCCUnionUnify       | 193 |
| Geometry.OffsetX             | 193 |
| Geometry.OffsetY             | 193 |
| Geometry.OffsetZ             | 193 |
| Geometry.OldCircle           | 193 |
| Geometry.OldNewReg           | 193 |
| Geometry.OldRuledSurface     | 193 |
| Geometry.OrientedPhysicals   | 194 |
| Geometry.PointNumbers        | 194 |
| Geometry.Points              | 194 |
| Geometry.PointSelectSize     | 194 |
| Geometry.PointSize           | 194 |
| Geometry.PointType           | 194 |
| Geometry.ReparamOnFaceRobust | 194 |
| Geometry.ScalingFactor       | 194 |
| Geometry.SnapX               | 194 |
| Geometry.SnapY               | 194 |
| Geometry.SnapZ               | 195 |
| Geometry.SurfaceNumbers      | 195 |
| Geometry.Surfaces            | 195 |
| Geometry.SurfaceType         | 195 |
| Geometry.Tangents            | 195 |
| Geometry.Tolerance           | 195 |
| Geometry.ToleranceBoolean    | 195 |
| Geometry.Transform           | 195 |
| Geometry.TransformXX         | 195 |
| Geometry.TransformXY         | 195 |
| Geometry.TransformZ          | 196 |
| Geometry.TransformZX         | 196 |
| Geometry.TransformYZ         | 196 |
| Geometry.VolumeNumbers       | 196 |
| Geometry.Volumes             | 196 |

| gmsh/clear                   | 251 |
| gmsh/finalize                | 251 |
| gmsh/fltk/awake              | 298 |
| gmsh/fltk/isAvailable        | 298 |
| gmsh/fltk/lock               | 298 |
| gmsh/fltk/selectElements     | 299 |
| gmsh/fltk/selectEntities     | 299 |
| gmsh/fltk/selectViews        | 299 |
| gmsh/fltk/setEnabled         | 298 |
| gmsh/fltk/wait               | 297 |
| gmsh/graphics/write          | 297 |
| gmsh/initialize              | 250 |
| gmsh/logger/get              | 301 |
| gmsh/logger/getCpuTime       | 301 |
| gmsh/logger/getWallTime      | 301 |
| gmsh/logger/start            | 301 |
| gmsh/logger/stop             | 301 |
| gmsh/logger/write            | 300 |
| gmsh/merge                   | 251 |
| gmsh/model/add               | 253 |
| gmsh/model/addDiscreteEntity | 256 |
| gmsh/model/addPhysicalGroup  | 255 |
| gmsh/model/addBezier         | 277 |
| gmsh/model/addBSpline        | 277 |
| gmsh/model/addCircleArc      | 276 |
| gmsh/model/addCompoundBSpline| 278 |
| gmsh/model/addCompoundSpline | 277 |
| gmsh/model/addCurveSurface   | 278 |
| gmsh/model/addEllipseArc     | 277 |
| gmsh/model/addLine           | 276 |
| gmsh/model/addPlaneSurface   | 278 |
| gmsh/model/addPoint          | 276 |
| gmsh/model/addSpline         | 277 |
| gmsh/model/addSurfaceFilling | 278 |
| gmsh/model/addSurfaceLoop    | 278 |
| gmsh/model/addVolume         | 279 |
| gmsh/model/addGeometry       | 281 |
| gmsh/model/addDilate         | 280 |
| gmsh/model/addExtrude        | 279 |
| gmsh/model/addMeshAlgorithm  | 283 |
| gmsh/model/addMeshRecombine  | 282 |
| gmsh/model/addMeshReverse    | 283 |
| gmsh/model/addMeshSize       | 281 |
| gmsh/model/addMeshSetSizeFromBoundary | 283 |
| gmsh/model/addMeshSetSmoothing| 282 |
| gmsh/model/addMeshSetTransfiniteCurve | 282 |
| gmsh/model/addMeshSetTransfiniteSurface | 282 |
Mesh.Width
Mesh.MaxIterDelaunay3D
Mesh.MaxNumThreads1D
Mesh.MaxNumThreads2D
Mesh.MaxNumThreads3D
Mesh.MaxRetries
Mesh.MeshFileMinorVersion
Mesh.MeshOnlyVisible
Mesh.MeshPartitionPyramidWeight
Mesh.MeshPartitionLineWeight
Mesh.MeshPartitionHexWeight
Mesh.MeshPartitionCreatePhysicals
Mesh.MeshOptimize
Mesh.MeshNewtonConvergenceTestXYZ
Mesh.MeshNbTriangles
Mesh.MeshNbTetrahedra
Mesh.MeshNbNodes
Mesh.MeshNbPartitions
Mesh.MeshNbPyramids
Mesh.MeshNbQuadrangles
Mesh.MeshIdentification
Mesh.MeshIdentification2D
Mesh.MeshIdentification3D
Mesh.MeshSaveElementTagType
Mesh.MeshSaveAll
Mesh.MeshRecombine3DAll
Mesh.MeshRecombine3DLevel
Mesh.MeshRecombineAll
Mesh.MeshRecombineOptimizeTopology
Mesh.MeshRecombineIncomplete
Mesh.MeshRecombineLinear
Mesh.MeshSmoothCrossField
Mesh.MeshSmoothNormals
Mesh.MeshSmoothRatio
Mesh.MeshStlAngularDeflection
Mesh.MeshStlLinearDeflection
Mesh.MeshStlOneSolidPerSurface
Mesh.MeshStlRemoveDuplicateTriangles
Mesh.MeshSubdivisionAlgorithm
Mesh.MeshSurfaceEdges
Mesh.MeshSurfaceFaces
Mesh.MeshSurfaceNumbers
Mesh.MeshSwitchElementTags
Mesh.MeshTangents
Mesh.MeshTetrahedra
Mesh.MeshToleranceEdgeLength
Mesh.MeshToleranceInitialDelaunay
Mesh.MeshTriangles
Mesh.MeshTrihedra
Mesh.MeshUnvStrictFormat
Mesh.MeshVolumeEdges
Mesh.MeshVolumeFaces
Mesh.MeshVolumeNumbers
Mesh.MeshVoronoi
Mesh.MeshZoneDefinition
Mesh.MeshAlgorithm Surface { expression-list } =
Mesh.MeshSizeFromBoundary Surface { expression-list } = expression;
Min
Min ( expression, expression )
MinAniso
Modulo ( expression, expression )
MPI_Rank
MPI_Size...30

N
newl...30
newl1...30
NewModel...34
new...30
newreg...30
news...30
newv...30
NonBlockingSystemCall char-expression;...34

O
Octree
OnelabRun (char-expression <,
  char-expression > ) ...34
operator-binary...25
operator-ternary-left...25
operator-ternary-right...25
operator-uneary-left...25
operator-uneary-right...25
OptimizeMesh char-expression;...70

P
Param...64
PartitionMesh expression;...70
Periodic Curve { expression-list } = {expression-list};...71
Periodic Curve | Surface { expression-list } = {expression-list} Affine Translate {expression-list};...71
Periodic Curve | Surface { expression-list } = {expression-list} Rotate {expression-list}, {expression-list}, expression;...71
Periodic Surface expression { expression-list } = expression { expression-list };...71
Physical Curve (expression | char-expression <, expression> ) <\|-> {expression-list};...39
Physical Point (expression | char-expression <, expression> ) <\|-> {expression-list};...38
Physical Surface (expression | char-expression <, expression> ) <\|-> {expression-list};...40
Physical Volume (expression | char-expression <, expression> ) <\|-> {expression-list};...41
Pi...30
Plane Surface (expression ) = {expression-list};...39
Plugin (string). Run;...79

Plugin (string). string = expression |
  char-expression;...79
Plugin (AnalyseMeshQuality)...82
Plugin (Annotate)...83
Plugin (BoundaryAngles)...84
Plugin (Bubbles)...84
Plugin (Crack)...84
Plugin (Curl)...85
Plugin (CurvedBndDist)...85
Plugin (CutBox)...85
Plugin (CutGrid)...86
Plugin (CutMesh)...87
Plugin (CutParametric)...87
Plugin (CutPlane)...88
Plugin (CutSphere)...88
Plugin (DiscretizationError)...89
Plugin (Distance)...89
Plugin (Divergence)...90
Plugin (Eigenvalues)...90
Plugin (Eigenvectors)...90
Plugin (ExtractEdges)...90
Plugin (ExtractElements)...91
Plugin (FieldFromAmplitudePhase)...91
Plugin (GaussPoints)...91
Plugin (Gradient)...92
Plugin (HarmonicToTime)...92
Plugin (HomologyComputation)...92
Plugin (HomologyPostProcessing)...93
Plugin (Integrate)...94
Plugin (Isosurface)...95
Plugin (Lambda2)...95
Plugin (LongitudeLatitude)...96
Plugin (MakeSimplex)...96
Plugin (MathEval)...96
Plugin (MeshSizeFieldView)...98
Plugin (MeshSubEntities)...98
Plugin (MeshVolume)...98
Plugin (MinMax)...98
Plugin (ModifyComponents)...99
Plugin (ModulusPhase)...100
Plugin (NearestNeighbor)...101
Plugin (NearToFarField)...100
Plugin (NewView)...102
Plugin (Particles)...102
Plugin (Probe)...103
Plugin (Remove)...103
Plugin (Scalar2Tens)...104
Plugin (Scalar2Vec)...104
Plugin (ShowNeighborElements)...105
Plugin (SimplePartition)...105
Plugin (Skin)...105
Plugin (Smooth)...106
Plugin (SphericalRaise)...106
Plugin (Streamlines)...106
Plugin (Summation)...107
Plugin (Tetrahedralize)...108
Plugin (Transform)...108
Plugin (Triangulate)...109
Smooth Surface { expression-list } =
In Sphere { expression-list };  
S
Solver.AlwaysListen ......................... 220
Solver.AutoArchiveOutputFiles ............. 220
Solver.AutoCheck ............................ 220
Solver.AutoLoadDatabase .................... 220
Solver.AutoMergeFile ....................... 220
Solver.AutoMesh ............................. 220
Solver.AutoSaveDatabase .................... 220
Solver.AutoShowLastStep ................. 220
Solver.AutoShowViews ...................... 220
Solver.Executable0 ........................ 217
Solver.Executable1 ......................... 217
Solver.Executable2 ......................... 217
Solver.Executable3 ......................... 217
Solver.Executable4 ........................ 218
Solver.Executable5 ......................... 218
Solver.Executable6 ......................... 218
Solver.Executable7 ......................... 218
Solver.Executable8 ......................... 218
Solver.Executable9 ........................ 218
Solver.Name0 ............................... 218
Solver.Name1 ............................... 218
Solver.Name2 ............................... 218
Solver.Name3 ............................... 218
Solver.Name4 ............................... 219
Solver.Name5 ............................... 219
Solver.Name6 ............................... 219
Solver.Name7 ............................... 219
Solver.Name8 ............................... 219
Solver.Name9 ............................... 219
Solver.OctaveInterpreter ................... 220
Solver.Plugins ............................. 220
Solver.PythonInterpreter ................... 220
Solver.RemoteLogin0 ....................... 220
Solver.RemoteLogin1 ....................... 220
Solver.RemoteLogin2 ....................... 220
Solver.RemoteLogin3 ....................... 220
Solver.RemoteLogin4 ....................... 220
Solver.RemoteLogin5 ....................... 220
Solver.RemoteLogin6 ....................... 220
Solver.RemoteLogin7 ....................... 220
Solver.RemoteLogin8 ....................... 220
Solver.RemoteLogin9 ....................... 220
Solver.ShowInvisibleParameters .......... 220
Solver.SocketName ......................... 220
Solver.Timeout ............................. 223
Sphere ( expression ) = { expression-list };
Spline ( expression ) = { expression-list };
Sqrt ( expression ) .......................... 228
string *= expression; ....................... 231
string += { expression-list }; ............ 231
string *= expression; ....................... 231
string -= { expression-list }; ............ 231
string -= expression; ....................... 231
string /= expression; ....................... 231
string = { }; ............................... 231
string = char-expression; ................. 231
string = expression; ....................... 231
string { { expression-list } } *= {  
expression-list }; ......................... 231
string { { expression-list } } += {  
expression-list }; ......................... 231
string { { expression-list } } -= {  
expression-list }; ......................... 231
string { { expression-list } } /= {  
expression-list }; ......................... 231
string { { expression-list } } = {  
expression-list }; ......................... 231
string[] += Str( char-expression-list );
string[] = { expression-list }; .......... 231
string[] = Str( char-expression-list ); 31
Structured ................................ 65
Surface ( expression ) = { expression-list } <  
In Sphere { expression } >; .............. 40
Surface Loop { expression } = {
  expression-list } < Using Sewing >; ... 40
Symmetry { expression-list } { transform-list }; ... 45
SyncModel; ... 34
SystemCall char-expression; ... 34

T
Tan ( expression ) ... 28
Tan( ( expression ) ... 28
Threshold ... 66
ThruSections { expression } = {
  expression-list }; ... 41
ThruSections { expression-list } ... 42
Torus ( expression ) = { expression-list };
TotalMemory ... 41
Transfinite Curve { expression-list-or-all }
  = expression < Using Progression | Bump
  expression >; ... 69
Transfinite Surface { expression-list-or-all }
  } = { expression-list } << Left | Right
  | Alternate | AlternateRight |
  AlternateLeft > ; ... 69
Transfinite Volume { expression-list } = { expression-list } > ; ... 69
transform ...
TransfQuadTri { expression-list } ... 70
Translate { expression-list }
  transform-list } ... 45

V
View "string" { string < ( expression-list ) >
  { expression-list }; ... } ... 79
View.AbsissaRangeType ... 227
View.AdaptVisualizationGrid ... 227
View.AngleSmoothNormals ... 228
View.ArrowSizeMax ... 228
View.ArrowSizeMin ... 228
View.Attributes ... 225
View.AutoComplete ... 228
View.Axes ... 228
View.AxesAutoPosition ... 228
View.AxesFormatX ... 225
View.AxesFormatY ... 225
View.AxesFormatZ ... 225
View.AxesLabelX ... 225
View.AxesLabelY ... 225
View.AxesLabelZ ... 225
View.AxesMaxX ... 228
View.AxesMaxY ... 228
View.AxesMaxZ ... 228
View.AxesMikado ... 228
View.AxesMinX ... 229
View.AxesMinY ... 229
View.AxesMinZ ... 229
View.AxesTicsX ... 229
View.AxesTicsY ... 229
View.AxesTicsZ ... 229
View.Boundary ... 229
View.CenterGlyphs ... 229
View.Clip ... 229
View.Closed ... 229
View.Color.Axes ... 241
View.Color.Background2D ... 241
View.Color.Hexahedra ... 240
View.Color.Lines ... 240
View.Color.Normals ... 241
View.Color.Points ... 240
View.Color.Prisms ... 240
View.Color.Pyramids ... 240
View.Color.Quadrangles ... 240
View.Color.Tangents ... 241
View.Color.Tetrahedra ... 240
View.Color.Text2D ... 241
View.Color.Text3D ... 241
View.Color.Triangles ... 240
View.Color.Trihedra ... 241
View.ColormapAlpha ... 230
View.ColormapAlphaPower ... 230
View.ColormapBeta ... 230
View.ColormapBias ... 230
View.ColormapCurvature ... 230
View.ColormapInvert ... 230
View.ColormapNumber ... 230
View.ColormapRotation ... 230
View.ColormapSwap ... 230
View.ColorTable ... 241
View.ComponentMap0 ... 230
View.ComponentMap1 ... 231
View.ComponentMap2 ... 231
View.ComponentMap3 ... 231
View.ComponentMap4 ... 231
View.ComponentMap5 ... 231
View.ComponentMap6 ... 231
View.ComponentMap7 ... 231
View.ComponentMap8 ... 231
View.ComponentMap9 ... 231
View.ComponentMap10 ... 231
View.ComponentMap11 ... 231
View.ComponentMap12 ... 231
View.ComponentMap13 ... 231
View.ComponentMap14 ... 231
View.ComponentMap15 ... 231
View.ComponentMap16 ... 231
View.ComponentMap17 ... 231
View.ComponentMap18 ... 231
View.ComponentMap19 ... 231
View.ComponentMap20 ... 231
View.ComponentMap21 ... 231
View.ComponentMap22 ... 231
View.ComponentMap23 ... 231
View.ComponentMap24 ... 231
View.ComponentMap25 ... 231
View.ComponentMap26 ... 231
View.ComponentMap27 ... 231
View.ComponentMap28 ... 231
View.ComponentMap29 ... 231
View.ComponentMap30 ... 231
View.ComponentMap31 ... 231
View.ComponentMap32 ... 231
View.ComponentMap33 ... 231
View.ComponentMap34 ... 231
View.ComponentMap35 ... 231
View.ComponentMap36 ... 231
View.ComponentMap37 ... 231
View.ComponentMap38 ... 231
View.ComponentMap39 ... 231
View.ComponentMap40 ... 231
View.ComponentMap41 ... 231
View.ComponentMap42 ... 231
View.ComponentMap43 ... 231
View.ComponentMap44 ... 231
View.ComponentMap45 ... 231
View.ComponentMap46 ... 231
View.ComponentMap47 ... 231
View.ComponentMap48 ... 231
View.ComponentMap49 ... 231
View.ComponentMap50 ... 231
View.ComponentMap51 ... 231
View.ComponentMap52 ... 231
View.ComponentMap53 ... 231
View.ComponentMap54 ... 231
View.ComponentMap55 ... 231
View.ComponentMap56 ... 231
View.ComponentMap57 ... 231
View.ComponentMap58 ... 231
View.ComponentMap59 ... 231
View.ComponentMap60 ... 231
View.ComponentMap61 ... 231
View.ComponentMap62 ... 231
View.ComponentMap63 ... 231
View.ComponentMap64 ... 231
View.ComponentMap65 ... 231
View.ComponentMap66 ... 231
View.ComponentMap67 ... 231
View.ComponentMap68 ... 231
View.ComponentMap69 ... 231
View.ComponentMap70 ... 231
View.ComponentMap71 ... 231
View.ComponentMap72 ... 231
View.ComponentMap73 ... 231
View.ComponentMap74 ... 231
View.ComponentMap75 ... 231
View.ComponentMap76 ... 231
View.ComponentMap77 ... 231
View.ComponentMap78 ... 231
View.ComponentMap79 ... 231
View.ComponentMap80 ... 231
View.ComponentMap81 ... 231
View.ComponentMap82 ... 231
View.ComponentMap83 ... 231
View.ComponentMap84 ... 231
View.ComponentMap85 ... 231
View.ComponentMap86 ... 231
View.ComponentMap87 ... 231
View.ComponentMap88 ... 231
View.ComponentMap89 ... 231
View.ComponentMap90 ... 231
View.ComponentMap91 ... 231
View.ComponentMap92 ... 231
View.ComponentMap93 ... 231
View.ComponentMap94 ... 231
View.ComponentMap95 ... 231
View.ComponentMap96 ... 231
View.ComponentMap97 ... 231
View.ComponentMap98 ... 231
View.ComponentMap99 ... 231
View.ComponentMap100 ... 231
View.ComponentMap101 ... 231
View.ComponentMap102 ... 231
View.ComponentMap103 ... 231
View.ComponentMap104 ... 231
View.ComponentMap105 ... 231
View.ComponentMap106 ... 231
View.ComponentMap107 ... 231
View.ComponentMap108 ... 231
View.ComponentMap109 ... 231
View.ComponentMap110 ... 231
View.ComponentMap111 ... 231
View.ComponentMap112 ... 231
View.ComponentMap113 ... 231
View.ComponentMap114 ... 231
View.ComponentMap115 ... 231
View.ComponentMap116 ... 231
View.ComponentMap117 ... 231
View.ComponentMap118 ... 231
View.ComponentMap119 ... 231
View.ComponentMap120 ... 231
View.ComponentMap121 ... 231
View.ComponentMap122 ... 231
View.ComponentMap123 ... 231
View.ComponentMap124 ... 231
View.ComponentMap125 ... 231
View.ComponentMap126 ... 231
View.ComponentMap127 ... 231
View.ComponentMap128 ... 231
View.ComponentMap129 ... 231
View.ComponentMap130 ... 231
View.ComponentMap131 ... 231
View.ComponentMap132 ... 231
View.ComponentMap133 ... 231
View.ComponentMap134 ... 231
View.ComponentMap135 ... 231
View.ComponentMap136 ... 231
View.ComponentMap137 ... 231
View.ComponentMap138 ... 231
View.ComponentMap139 ... 231
View.ComponentMap140 ... 231
View.ComponentMap141 ... 231
View.ComponentMap142 ... 231
View.ComponentMap143 ... 231
View.ComponentMap144 ... 231
View.ComponentMap145 ... 231
View.ComponentMap146 ... 231
View.ComponentMap147 ... 231
View.ComponentMap148 ... 231
View.ComponentMap149 ... 231
View.ComponentMap150 ... 231
View.ComponentMap151 ... 231
View.ComponentMap152 ... 231
View.ComponentMap153 ... 231
View.ComponentMap154 ... 231
View.ComponentMap155 ... 231
View.ComponentMap156 ... 231
View.ComponentMap157 ... 231
View.ComponentMap158 ... 231
View.ComponentMap159 ... 231
View.ComponentMap160 ... 231
View.ComponentMap161 ... 231
View.ComponentMap162 ... 231
View.ComponentMap163 ... 231
View.DrawingDataTranspose ... 232
View.DrawHexahedra ... 232
View.DrawLines ... 232
View.DrawPoints ... 232
View.DrawPrisms ... 232
View.DrawPyramids ... 232
View.DrawQuadrangles ... 232
View.DrawScalars ... 233
View.DrawSkinOnly ... 233
View.DrawStrings ... 233
View.DrawTensors ... 233
View.DrawTetrahedra ... 233