



fc oogmsh Matlab toolbox, User's Guide*

version 0.2.2

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Abstract

This Matlab toolbox make it possible to generate mesh files from *.geo* files by using `gmsh`. It's also possible with the `ooGMSH2` and `ooGMSH4` classes to read the mesh file (respectively for MSH file format version 2.2 and version 4.x). This toolbox must be regarded as a very simple interface between `gmsh` files and Matlab. So you are free to create any data structures or objects you want from an `ooGMSH2` object or an `ooGMSH4` object.

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* $\text{\LaTeX}$ manual, revision 0.2.2, compiled with Matlab 2019a, and toolboxes `fc-oogmsh`[0.2.2], `fc-tools`[0.0.30], `fc-bench`[0.1.2], `fc-amat`[0.1.2], `fc-meshtools`[0.1.3], `fc-graphics4mesh`[0.1.1], and using `gmsh` 4.5.1

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1 Introduction

The **ooGmsh** Matlab toolbox is closely related to **gmsh**, see [2] or [3], which is a three-dimensional finite element mesh generator with built-in pre- and post-processing facilities. **gmsh** can also build two-dimensional meshes and three-dimensional surface meshes. This toolbox was initially created to make it possible from Matlab to rapidly

- generate mesh file from .geo file by using **gmsh**
- efficiently read this mesh file and store its contents in **ooGmsh** Matlab object easy to manipulate.

The **ooGmsh** Matlab object can be used to create, from a .msh file, any data structures or objects needed by your project. For example, the **fc-simesh** Matlab toolbox uses this toolbox to create the **siMesh** object containing all the simplices elements of the mesh.

This toolbox was tested on various OS with **gmsh** (versions 4.5.2, 4.4.1, 4.3.0, 4.2.3, 4.1.5, 4.0.7, 3.0.6 and 2.16.0) and Matlab releases:

Operating system	2017a	2017b	2018a	2018b	2019a
CentOS 7.7.1908	✓	✓	✓	✓	✓
Debian 9.11	✓	✓	✓	✓	✓
Fedora 29	✓	✓	✓	✓	✓
OpenSUSE Leap 15.0	✓	✓	✓	✓	✓
Ubuntu 18.04.3 LTS	✓	✓	✓	✓	✓
MacOS High Sierra 10.13.6	✓	✓	✓	✓	✓
MacOS Mojave 10.14.4	✓	✓	✓	✓	✓
MacOS Catalina 10.15.2	✓	✓	✓	✓	✓
Windows 10 (1909)	✓	✓	✓	✓	✓

It is not compatible with Matlab releases prior to R2015b.

Firstly, we explain how to configure the **fc_oogmsh** toolbox for using **gmsh**. Thereafter, we describe the **fc_oogmsh**'s functions which use **gmsh** to create mesh files.

2 Installation

2.1 Installation automatic, all in one (recommended)

For automatic installation, one has to get/download the install file

`mfc_oogmsh_install.m`

or get it on the dedicated web page. Thereafter, one run it under Matlab. This command download, extract and configure the *fc-oogmsh* toolbox and the required toolboxes *fc-tools*, *fc-meshtools* and *fc-graphics4mesh*, in the current directory.

By default, the gmsh binary is supposed to be located in

- <USERDIR>/bin/gmsh under linux,
- <USERDIR>/GMSH/Gmsh.app/Contents/MacOS/gmsh under Mac OS X,
- <USERDIR>/Softwares/GMSH/gmsh.exe under Windows

To specify an other location one can do

```
>> mfc_oogmsh_install('gmsh_bin', GMSH)
```

where **GMSH** is the gmsh binary with path as a string. It's also possible, after installation, to change the gmsh binary by using the Matlab command

```
>> fc_oogmsh.configure('gmsh_bin','~/gmsh-4.2.2/bin/gmsh')
```

For example, to install this toolbox in `~/Matlab` directory, one have to copy the file `mfc_oogmsh_install.m` in the `~/Matlab` directory. Then in a Matlab terminal run the following commands

```
>> cd ~/Matlab
>> mfc_oogmsh_install
```

There is the output of the `mfc_oogmsh_install` command on a Linux computer:

```
Parts of the <fc-oogmsh> Matlab toolbox.
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1- Downloading and extracting the toolboxes
2- Setting the <fc-oogmsh> toolbox
Write in ~/Matlab/fc-oogmsh-full/fc_oogmsh-0.2.2/configure_loc.m ...
3- Using toolboxes :
->          fc-tools : 0.0.30
->          fc-bench : 0.1.2
->          fc-amat : 0.1.2
->          fc-meshtools : 0.1.3
->          fc-graphics4mesh : 0.1.1
with          fc-oogmsh : 0.2.2
*** Using instructions
To use the <fc-oogmsh> toolbox:
addpath('~/Matlab/fc-oogmsh-full/fc_oogmsh-0.2.2')
fc_oogmsh.init()

See ~/Matlab/mfc_oogmsh_set.m
```

The complete toolbox (i.e. with all the other needed toolboxes) is stored in the directory

`~/Matlab/fc-oogmsh-full`

and, for each Matlab session, one has to set the toolbox by:

```
>> addpath('~/Matlab/fc-oogmsh-full/mfc-oogmsh-0.2.2')
>> fc_oogmsh.init()
```

If it's the first time the `fc_oogmsh.init()` function is used, then its output is

```
Try to use default parameters!
Use fc_tools.configure to configure.
Write in ~/Matlab/fc-oogmsh-full/fc_tools-0.0.30/configure_loc.m ...
Try to use default parameters!
Use fc_bench.configure to configure.
Write in ~/Matlab/fc-oogmsh-full/fc_bench-0.1.2/configure_loc.m ...
Try to use default parameters!
Use fc_amat.configure to configure.
Write in ~/Matlab/fc-oogmsh-full/fc_amat-0.1.2/configure_loc.m ...
Try to use default parameters!
Use fc_meshtools.configure to configure.
Write in ~/Matlab/fc-oogmsh-full/fc_meshtools-0.1.3/configure_loc.m ...
Try to use default parameters!
Use fc_graphics4mesh.configure to configure.
Write in ~/Matlab/fc-oogmsh-full/fc_graphics4mesh-0.1.1/configure_loc.m ...
Using fc_oogmsh[0.2.2] with fc_tools[0.0.30], fc_bench[0.1.2], fc_amat[0.1.2], ...
fc_meshtools[0.1.3], fc_graphics4mesh[0.1.1].
Configured to use gmsh 4.5.1 with default MSH file format version 4.1
```

Otherwise, the output of the `fc_oogmsh.init()` function is

```
Using fc_oogmsh[0.2.2] with fc_tools[0.0.30], fc_bench[0.1.2], fc_amat[0.1.2], ...
fc_meshtools[0.1.3], fc_graphics4mesh[0.1.1].
Configured to use gmsh 4.5.1 with default MSH file format version 4.1
```

For **uninstalling**, one just has to delete directory:

~/Matlab/fc-oogmsh-full

3 gmsh interface

All functions provided in this section use `gmsh` to create a mesh file from a `gmsh` geometry script file (extension `.geo`).

3.1 function `fc_oogmsh.gmsh.buildmesh2d`

This function uses `gmsh` and a `.geo` file (describing a 2D-geometry) to generate a 2D-mesh.

Syntaxe

```
meshfile=fc_oogmsh.gmsh.buildmesh2d(geofile,N)

meshfile=fc_oogmsh.gmsh.buildmesh2d(geofile,N,Name,Value)
```

Description

`meshfile=fc_oogmsh.gmsh.buildmesh2d(geofile,N)` create a 2D-mesh using `gmsh` and the `geo` file `geofile` (without path). The integer `N` has two functions : numbering the name of the generated mesh as `<geofile without extension and path> + <-N.msh>` and passing this number to `gmsh` via the option `"-setnumber N <N>".` Usually we used this parameter in `gmsh` to set the prescribed mesh element size at the points. (see given `geo` files)

As output return a file name (with full path) corresponding to the mesh generated by `gmsh`.

`meshfile=fc_oogmsh.gmsh.buildmesh2d(geofile,N,Name,Value, ...)` specifies function options using one or more `Name,Value` pair arguments. The `Name` options can be

- `'geodir'` : to specify the directory of the `geo` file `geofile`,
- `'meshdir'` : to specify the directory where the mesh file will be written,

- **'meshfile'** : to specify the name of the mesh file (with path and **.msh** extension),
- **'check'** : to perform various consistency checks on mesh with **gmsh**, if **Value** is **true**. (default : **false**)
- **'force'** : to force meshing even if the mesh file already exists if **Value** is **true** (default : **false**)
- **'verbose'** : to specify the degree of verbosity (0, silence; 2, default; ...)
- **'strings'** : cells array of strings corresponding to **gmsh** options given with **-string "..."** (default empty) (see **gmsh** documentation). For example, **Value** could be:

```
{'Mesh.Algorithm=1;', 'Mesh.ScalingFactor=2;'}
```

- **'MshFileVersion'** : to specify the MSH file format version. **Value** could be
 - **'2.2'** if **gmsh** version $\geq$ 2.16.0,
 - **'4.0'** if **gmsh** version $\geq$ 4.0.0,
 - **'4.1'** if **gmsh** version $\geq$ 4.1.0.

Examples All the following examples use the **.geo** file **condenser11.geo** which is in the directory **geodir** of the toolbox.

Matlab code with output

```
disp('****_fc_oogmsh.gmsh.buildmesh2d:_1st_call')
meshfile=fc_oogmsh.gmsh.buildmesh2d('condenser11',25,'force',true);
disp('****_fc_oogmsh.gmsh.buildmesh2d:_2nd_call')
meshfile=fc_oogmsh.gmsh.buildmesh2d('condenser11',25);
```

```
**** fc_oogmsh.gmsh.buildmesh2d : 1st call
[fc-oogmsh] Input file : <fc-oogmsh>/geodir/2d/condenser11.geo
[fc-oogmsh] Overwriting mesh file <fc-oogmsh>/meshes/condenser11-25.msh
[fc-oogmsh] Starting building mesh <fc-oogmsh>/meshes/condenser11-25.msh with gmsh 4.5.1
[fc-oogmsh] Using command : gmsh -2 -setnumber N 25 -string "Mesh.MshFileVersion=4.1;" <fc-oogmsh>/geodir/2d/condenser11.geo -o ...
<fc-oogmsh>/meshes/condenser11-25.msh
Be patient...
[fc-oogmsh] Using gmsh 4.5.1 to write MSH file format version 4.1 in <fc-oogmsh>/meshes/condenser11-25.msh
**** fc_oogmsh.gmsh.buildmesh2d : 2nd call
[fc-oogmsh] Input file : <fc-oogmsh>/geodir/2d/condenser11.geo
[fc-oogmsh] Mesh file <fc-oogmsh>/meshes/condenser11-25.msh [version 4.1] already exists.
-> Use "force" flag to rebuild if needed.
```

Matlab code with output

```
meshfile=fc_oogmsh.gmsh.buildmesh2d('condenser11',25,'force',true,...  
'verbose',4,'strings',{ 'Mesh.Algorithm=1;', 'Mesh.ScalingFactor=2;'});
```

```
[fc-oogmsh] Input file : <fc-oogmsh>/geodir/2d/condenser11.geo  
[fc-oogmsh] Overwriting mesh file <fc-oogmsh>/meshes/condenser11-25.msh  
[fc-oogmsh] Starting building mesh <fc-oogmsh>/meshes/condenser11-25.msh with gmsh 4.5.1  
[fc-oogmsh] Using command : gmsh -2 -setnumber N 25 -string "Mesh.Algorithm=1;Mesh.ScalingFactor=2;Mesh.MshFileVersion=4.1;" ...  
<fc-oogmsh>/geodir/2d/condenser11.geo -o <fc-oogmsh>/meshes/condenser11-25.msh  
Be patient...  
[fc-oogmsh] gmsh output :  
Info : Running 'fcopt/GMSH/64bit/4.5.1/bin/gmsh -2 -setnumber N 25 -string Mesh.Algorithm=1;Mesh.ScalingFactor=2;Mesh.MshFileVersion=4.1; ...  
<fc-oogmsh>/geodir/2d/condenser11.geo -o <fc-oogmsh>/meshes/condenser11-25.msh' [Gmsh 4.5.1, 1 node, max. 1 thread]  
Info : Started on Mon Feb 17 18:15:36 2020  
Info : Reading '<fc-oogmsh>/geodir/2d/condenser11.geo'...  
Info : Reading '<fc-oogmsh>/geodir/2d/options01_data.geo'...  
Info : Done reading '<fc-oogmsh>/geodir/2d/options01_data.geo'  
Info : Reading '<fc-oogmsh>/geodir/2d/shape_functions.geo'...  
Info : Done reading '<fc-oogmsh>/geodir/2d/shape_functions.geo'  
Info : Removing duplicate mesh nodes...  
Info : Found 0 duplicate nodes  
Info : No duplicate nodes found  
Info : Done reading '<fc-oogmsh>/geodir/2d/condenser11.geo'  
Info : Meshing 1D...  
Info : [ 0 %] Meshing curve 101 (Line)  
Info : [ 10 %] Meshing curve 102 (Line)  
Info : [ 10 %] Meshing curve 103 (Line)  
Info : [ 10 %] Meshing curve 104 (Line)  
Info : [ 10 %] Meshing curve 106 (Circle)  
Info : [ 20 %] Meshing curve 107 (Circle)  
Info : [ 20 %] Meshing curve 108 (Circle)  
Info : [ 20 %] Meshing curve 109 (Circle)  
Info : [ 20 %] Meshing curve 111 (Circle)  
Info : [ 30 %] Meshing curve 112 (Circle)  
Info : [ 30 %] Meshing curve 113 (Circle)  
Info : [ 30 %] Meshing curve 114 (Circle)  
Info : [ 30 %] Meshing curve 116 (Circle)  
Info : [ 40 %] Meshing curve 117 (Circle)  
Info : [ 40 %] Meshing curve 118 (Circle)  
Info : [ 40 %] Meshing curve 119 (Circle)  
Info : [ 40 %] Meshing curve 121 (Circle)  
Info : [ 50 %] Meshing curve 122 (Circle)  
Info : [ 50 %] Meshing curve 123 (Circle)  
Info : [ 50 %] Meshing curve 124 (Circle)  
Info : [ 50 %] Meshing curve 126 (Circle)  
Info : [ 60 %] Meshing curve 127 (Circle)  
Info : [ 60 %] Meshing curve 128 (Circle)  
Info : [ 60 %] Meshing curve 129 (Circle)  
Info : [ 60 %] Meshing curve 131 (Circle)  
Info : [ 70 %] Meshing curve 132 (Circle)  
Info : [ 70 %] Meshing curve 133 (Circle)  
Info : [ 70 %] Meshing curve 134 (Circle)  
Info : [ 70 %] Meshing curve 136 (Circle)  
Info : [ 80 %] Meshing curve 137 (Circle)  
Info : [ 80 %] Meshing curve 138 (Circle)  
Info : [ 80 %] Meshing curve 139 (Circle)  
Info : [ 80 %] Meshing curve 141 (Circle)  
Info : [ 90 %] Meshing curve 142 (Circle)  
Info : [ 90 %] Meshing curve 143 (Circle)  
Info : [ 90 %] Meshing curve 144 (Circle)  
Info : [ 90 %] Meshing curve 146 (Circle)  
Info : [100 %] Meshing curve 147 (Circle)  
Info : [100 %] Meshing curve 148 (Circle)  
Info : [100 %] Meshing curve 149 (Circle)  
Info : Done meshing 1D (0.02065 s)  
Info : Meshing 2D...  
Info : [ 0 %] Meshing surface 105 (Plane, MeshAdapt)  
Info : [ 20 %] Meshing surface 110 (Plane, MeshAdapt)  
Info : [ 40 %] Meshing surface 120 (Plane, MeshAdapt)  
Info : [ 50 %] Meshing surface 130 (Plane, MeshAdapt)  
Info : [ 70 %] Meshing surface 140 (Plane, MeshAdapt)  
Info : [ 90 %] Meshing surface 150 (Plane, MeshAdapt)  
Info : Done meshing 2D (1.57678 s)  
Info : 2895 nodes 5923 elements  
Info : Writing '<fc-oogmsh>/meshes/condenser11-25.msh'...  
Info : Done writing '<fc-oogmsh>/meshes/condenser11-25.msh'  
Info : Stopped on Mon Feb 17 18:15:37 2020  
  
[fc-oogmsh] Using gmsh 4.5.1 to write MSH file format version 4.1 in <fc-oogmsh>/meshes/condenser11-25.msh
```

3.2 function `fc_oogmsh.gmsh.buildmesh3d`

This function uses `gmsh` and a `.geo` file (describing a 3D-geometry) to generate a 3D-mesh. See function `gmsh.buildmesh2d` for usage and options (section 3.1).

3.3 function `fc_oogmsh.gmsh.buildmesh3ds`

This function uses `gmsh` and a `.geo` file (describing a 3D surface geometry or a 3D-geometry) to generate a 3D surface mesh. See function `gmsh.buildmesh2d` for usage and options (section 3.1).

3.4 function `fc_oogmsh.gmsh.buildpartmesh2d`

This function uses `gmsh` and a `.msh` file (containing a 2D-mesh) to generate a 2D partioned mesh.

Syntaxe

```
partmeshfile=fc_oogmsh.gmsh.buildpartmesh2d(meshfile,np)
partmeshfile=fc_oogmsh.gmsh.buildpartmesh2d(meshfile,np,Name,Value)
```

Description

`partmeshfile=fc_oogmsh.gmsh.buildpartmesh2d(meshfile,np)` create a 2D partitioned mesh using `gmsh` and the `msh` file `meshfile` (with path). The integer `np` is the number of partitions. As output return a file name (with full path) corresponding to the partitioned mesh generated by `gmsh`. The output file name is construct as following : `<meshfile without extension>-part<np>.msh`

`partmeshfile=fc_oogmsh.gmsh.buildpartmesh2d(meshfile,np,Name,Value,...)` specifies function options using one or more `Name,Value` pair arguments. The `Name` options can be

- `'savedir'` : to specify the directory where the partitioned mesh file will be written,
- `'check'` : to perform various consistency checks on mesh with `gmsh`, if `Value` is `true`. (default : `false`)
- `'force'` : to force meshing even if the mesh file already exists if `Value` is `true` (default : `false`)
- `'verbose'` : to specify the degree of verbosity (0, silence; 2, default; ...)
- `'strings'` : cells array of strings corresponding to `gmsh` options given with `-string "..."` (default empty) (see `gmsh` documentation)
- `'MshFileVersion'` : to specify the MSH file format version. `Value` could be
 - `'2.2'` if `gmsh` version $\geq 2.16.0$,
 - `'4.0'` if `gmsh` version $\geq 4.0.0$,
 - `'4.1'` if `gmsh` version $\geq 4.1.0$.

Examples

Matlab code with output

```
meshfile=fc_oogmsh.gmsh.buildmesh2d('condenser11',25,'verbose',0);
pmfile=fc_oogmsh.gmsh.buildpartmesh2d(meshfile,5,'force',true);
```

```
[fc-oogmsh] Input file : <fc-oogmsh>/meshes/condenser11-25.msh
[fc-oogmsh] Overwritting mesh file <fc-oogmsh>/meshes/condenser11-25-part5.msh
[fc-oogmsh] Starting building mesh <fc-oogmsh>/meshes/condenser11-25-part5.msh with gmsh 4.5.1
[fc-oogmsh] Using command : gmsh -2 -part 5 -string "Mesh.MshFileVersion=4.1;" -saveall <fc-oogmsh>/meshes/condenser11-25.msh -o ...
<fc-oogmsh>/meshes/condenser11-25-part5.msh
Be patient...
[fc-oogmsh] Using gmsh 4.5.1 to write MSH file format version 4.1 in <fc-oogmsh>/meshes/condenser11-25-part5.msh
```

Matlab code with output

```
meshfile=fc_oogmsh.gmsh.buildmesh2d('condenser11',25,'verbose',0);
pmfile=fc_oogmsh.gmsh.buildpartmesh2d(meshfile,5,'force',true,'verbose',4,...
    'strings',{'Mesh.MetisAlgorithm=3;'});
```

```
[fc-oogmsh] Input file : <fc-oogmsh>/meshes/condenser11-25.msh
[fc-oogmsh] Overwriting mesh file <fc-oogmsh>/meshes/condenser11-25-part5.msh
[fc-oogmsh] Starting building mesh <fc-oogmsh>/meshes/condenser11-25-part5.msh with gmsh 4.5.1
[fc-oogmsh] Using command : gmsh -2 -part 5 -string "Mesh.MetisAlgorithm=3;Mesh.MshFileVersion=4.1;" -saveall <fc-oogmsh>/meshes/condenser11-25.msh -o ...
    <fc-oogmsh>/meshes/condenser11-25-part5.msh
Be patient...
[fc-oogmsh] gmsh output :
Info : Running '/fcopt/GMSH/64bit/4.5.1/bin/gmsh -2 -part 5 -string Mesh.MetisAlgorithm=3;Mesh.MshFileVersion=4.1; -saveall ...
    <fc-oogmsh>/meshes/condenser11-25.msh -o <fc-oogmsh>/meshes/condenser11-25-part5.msh' [Gmsh 4.5.1, 1 node, max. 1 thread]
Info : Started on Mon Feb 17 18:15:57 2020
Info : Reading '<fc-oogmsh>/meshes/condenser11-25.msh'...
Info : 2886 nodes
Info : 5874 elements
Info : Done reading '<fc-oogmsh>/meshes/condenser11-25.msh'
Info : Meshing 1D...
Info : Done meshing 1D (8.9e-05 s)
Info : Meshing 2D...
Info : Done meshing 2D (8e-05 s)
Info : 2895 nodes 5923 elements
Info : Partitioning mesh...
Info : Running METIS with ptype:rb, ufactor:default, ctype:shem, rtype:greedy, objtype:cut, minconn:default
Info : 5 partitions, 148 total edge-cuts
Info : Done partitioning mesh (0.047403 s)
Info : - Repartition of 49 points: 5(min) 18(max) 9.8(avg)
Info : - Repartition of 360 lines: 66(min) 86(max) 72(avg)
Info : - Repartition of 5514 triangles: 1102(min) 1103(max) 1102.8(avg)
Info : Creating partition topology...
Info : - Creating partition curves
Info : - Creating partition points
Info : Done creating partition topology (0.006519 s)
Info : Writing '<fc-oogmsh>/meshes/condenser11-25-part5.msh'...
Info : Done writing '<fc-oogmsh>/meshes/condenser11-25-part5.msh'
Info : Stopped on Mon Feb 17 18:15:57 2020

[fc-oogmsh] Using gmsh 4.5.1 to write MSH file format version 4.1 in <fc-oogmsh>/meshes/condenser11-25-part5.msh
```

3.5 function `fc_oogmsh.gmsh.buildpartmesh3d`

This function uses `gmsh` and a `.msh` file (containing of a 3D-mesh) to generate a 3D partioned mesh. See function `gmsh.buildpartmesh2d` for usage and options (section 3.4).

3.6 function `fc_oogmsh.gmsh.buildpartmesh3ds`

This function uses `gmsh` and a `.msh` file (containing of a 3D surface mesh) to generate a 3D partioned surface mesh. See function `gmsh.buildpartmesh2d` for usage and options (section 3.4).

3.7 function `fc_oogmsh.gmsh.buildPartRectangle`

This function uses `gmsh` and the `geodir/rectanglepart.geo` file to generate a 2D regular partioned mesh of the rectangle $[0, L_x] \times [0, L_y]$ with $N_x \times N_y$ partitions.

Syntaxe

```
meshfile=fc_oogmsh.gmsh.buildpartrectangle(Lx,Ly,Nx,Ny,N)
meshfile=fc_oogmsh.gmsh.buildpartrectangle(Lx,Ly,Nx,Ny,N, Name, Value)
```

Description

`meshfile=fc_oogmsh.gmsh.buildpartrectangle(Lx,Ly,Nx,Ny,N)` create a 2D regular partitioned mesh using `gmsh` of the rectangle $[0, L_x] \times [0, L_y]$ with $N_x \times N_y$ partitions. The `N` parameter is passed to `gmsh` to set the prescribed mesh element size at the points
As output return a file name (with full path) corresponding to the partitioned mesh generated by `gmsh`. The default output file name is construct as following :

`sprintf('rectanglepart-Lx%.3f-Ly%.3f-Nx%d-Ny%d-N%d.msh',Lx,Ly,Nx,Ny,N)`

`meshfile=fc_oogmsh.gmsh.buildpartrectangle(Lx,Ly,Nx,Ny,N,Name,Value,...)` specifies function options using one or more `Name,Value` pair arguments (see the `fc_oogmsh.gmsh.buildmesh2d`, section 3.1).

Examples All the following examples ...

Matlab code with output

```
pmfile=fc_oogmsh.gmsh.buildpartrectangle(1,1,3,2,100,'force',true);
```

```
[fc-oogmsh] Input file : <fc-oogmsh>/geodir/2d/rectanglepart.geo
[fc-oogmsh] Overwriting mesh file <fc-oogmsh>/meshes/rectanglepart-Lx1.000-Ly1.000-Nx3-Ny2-N100.msh
[fc-oogmsh] Starting building mesh <fc-oogmsh>/meshes/rectanglepart-Lx1.000-Ly1.000-Nx3-Ny2-N100.msh with gmsh 4.5.1
[fc-oogmsh] Using command : gmsh -2 -string "Mesh.MshFileVersion=4.1;" -setnumber N 100 -setnumber NX 3 -setnumber NY 2 -setnumber LX 1 -setnumber LY 1 ...
<fc-oogmsh>/geodir/2d/rectanglepart.geo -o <fc-oogmsh>/meshes/rectanglepart-Lx1.000-Ly1.000-Nx3-Ny2-N100.msh
Be patient...
[fc-oogmsh] Using gmsh 4.5.1 to write MSH file format version 4.1 in <fc-oogmsh>/meshes/rectanglepart-Lx1.000-Ly1.000-Nx3-Ny2-N100.msh
```

Matlab code with output

```
pmfile=fc_oogmsh.gmsh.buildpartrectangle(1,1,3,2,100,'verbose',4, ...
'force',true,'meshfile','./toto.msh');
```

```
[fc-oogmsh] Input file : <fc-oogmsh>/geodir/2d/rectanglepart.geo
[fc-oogmsh] Starting building mesh ./toto.msh with gmsh 4.5.1
[fc-oogmsh] Using command : gmsh -2 -string "Mesh.MshFileVersion=4.1;" -setnumber N 100 -setnumber NX 3 -setnumber NY 2 -setnumber LX 1 -setnumber LY 1 ...
<fc-oogmsh>/geodir/2d/rectanglepart.geo -o ./toto.msh
Be patient...
[fc-oogmsh] gmsh output :
Info : Running '/fcopt/GMSH/64bit/4.5.1/bin/gmsh -2 -string Mesh.MshFileVersion=4.1; -setnumber N 100 -setnumber NX 3 -setnumber NY 2 -setnumber LX 1 ...
-setnumber LY 1 <fc-oogmsh>/geodir/2d/rectanglepart.geo -o ./toto.msh' [Gmsh 4.5.1, 1 node, max. 1 thread]
Info : Started on Mon Feb 17 18:16:17 2020
Info : Reading '<fc-oogmsh>/geodir/2d/rectanglepart.geo'...
Info : Reading '<fc-oogmsh>/geodir/2d/partitions01_data.geo'...
Info : Done reading '<fc-oogmsh>/geodir/2d/partitions01_data.geo'
Info : Reading '<fc-oogmsh>/geodir/2d/partitions_shape.geo'...
Info : Done reading '<fc-oogmsh>/geodir/2d/partitions_shape.geo'
Info : Done reading '<fc-oogmsh>/geodir/2d/rectanglepart.geo'
Info : Meshing 1D...
Info : [ 0 %] Meshing curve 1 (Line)
Info : [ 10 %] Meshing curve 2 (Line)
Info : [ 20 %] Meshing curve 3 (Line)
Info : [ 20 %] Meshing curve 4 (Line)
Info : [ 30 %] Meshing curve 5 (Line)
Info : [ 30 %] Meshing curve 6 (Line)
Info : [ 40 %] Meshing curve 7 (Line)
Info : [ 50 %] Meshing curve 8 (Line)
Info : [ 50 %] Meshing curve 9 (Line)
Info : [ 60 %] Meshing curve 10 (Line)
Info : [ 60 %] Meshing curve 11 (Line)
Info : [ 70 %] Meshing curve 12 (Line)
Info : [ 80 %] Meshing curve 13 (Line)
Info : [ 80 %] Meshing curve 14 (Line)
Info : [ 90 %] Meshing curve 15 (Line)
Info : [ 90 %] Meshing curve 16 (Line)
Info : [100 %] Meshing curve 17 (Line)
Info : Done meshing 1D (0.010594 s)
Info : Meshing 2D...
Info : [ 0 %] Meshing surface 19 (Plane, Frontal)
Info : [ 20 %] Meshing surface 21 (Plane, Frontal)
Info : [ 40 %] Meshing surface 23 (Plane, Frontal)
Info : [ 50 %] Meshing surface 25 (Plane, Frontal)
Info : [ 70 %] Meshing surface 27 (Plane, Frontal)
Info : [ 90 %] Meshing surface 29 (Plane, Frontal)
Info : Done meshing 2D (0.5307 s)
Info : 12092 nodes 24496 elements
Info : Writing './toto.msh'...
Info : Done writing './toto.msh'
Info : Stopped on Mon Feb 17 18:16:18 2020

[fc-oogmsh] Using gmsh 4.5.1 to write MSH file format version 4.1 in ./toto.msh
```

4 ooGmsh4 class (version 4.x)

The **ooGMSH4** class can be used to read **gmsh** mesh files with the MSH ASCII file format version 4.1 since **gmsh** 4.1.0 ([4], section 9.1) or version 4.0 since **gmsh** 4.0.0.

The **gmsh**'s native "MSH" file format (version 4.x) is used to store meshes and associated post-processing datasets either save as an ASCII file or a binary file with extension **.msh**. The focus of the **ooGMSH4** class is to read only meshes contained in an ASCII file. Currently, it is not planned to read post-processing datasets.

As described in [4], section 9.1: *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 geometrical entities (\$Entities), the partitioned entities (\$PartitionedEntities), the nodes \$Nodes), the elements (\$Elements), the periodicity relations (\$Periodic), the ghost elements (\$GhostElements) and the post-processing datasets (\$NodeData, \$ElementData, \$ElementNodeData).*

For each section, the **ooGMSH4** class has a property with corresponding name. The properties of this class are:

Properties of **ooGmsh4** class

dim	: space dimension (2 or 3)
nq	: number of nodes/vertices.
q	: nodes/vertices array with dimension dim -by- nq .
toGlobal	: ...
MeshFormat	: structure
PhysicalNames	: (optional), array of PhysicalName structure
Entities	: structure
PartitionedEntities	: (optional) structure
Nodes	: structure
Elements	: structure
PeriodicLinks	: (optional), array of PeriodicLink structure

The structures **MeshFormat**, **PhysicalNames**, **Entities**, **PartitionedEntities**, **Nodes**, **Elements** and **PeriodicLinks** are described in section 4.2. In the following subsections, **Gh** is an **ooGmsh4** object.

4.1 Methods

4.1.1 ooGmsh4 constructor

The **ooGmsh4** class have only one constructor :

```
Gh=fc_oogmsh.ooGmsh4( meshfile )
Gh=fc_oogmsh.ooGmsh4( meshfile , 'verbosity' , Value )
```

where **meshfile** is the name of ... a mesh file. The '**verbosity**' Key/Value option can be used to print some informations, when reading the file **meshfile**, if **Value** is **true**. Default is **false**

Matlab code with output

```
fprintf( '1)_Building_the_mesh\n' )
meshfile=fc_oogmsh.gmsh.buildmesh2d( 'condenser' ,10 , ...
    'verbose' ,0 , 'force' ,true );
fprintf( '2)_Reading_the_mesh\n' );
Gh = fc_oogmsh.ooGmsh4( meshfile , 'verbose' ,true );
fprintf( ' ->_Gh_is_an_ooGmsh4_object_containing_a_MSH_file_version_...
    %s\n' ,Gh.MeshFormat.version )
fprintf( '3)_Displaying_Gh\n' );
Gh
```

```
1) Building the mesh
[fc-oogmsh] Using gmsh 4.5.1 to write MSH file format version 4.1 in <fc-oogmsh>/meshes/condenser-10.msh
2) Reading the mesh
Optional string "$PhysicalNames" not found
Reading $Entities section seem OK
Optional string "$PartitionedEntities" not found
Reading $Nodes section seem OK
Reading $Elements section seem OK
Optional string "$Periodic" not found
-> Gh is an ooGmsh4 object containing a MSH file version 4.1
3) Displaying Gh

Gh =

fc_oogmsh.ooGmsh4 with properties:
    q: (2x8151 double)
    nq: 8151 double
    dim: 2 double
    d: 2 double
    toGlobal: (1x8151 double)
    meshfile: (1x110 char)
    partitionedfile: 0 logical
    MeshFormat: (1x1 struct)
        PhysicalNames: []
        Entities: (1x1 struct)
    PartitionedEntities: []
    Nodes: (1x1 struct)
    Elements: (1x1 struct)
    PeriodicLinks: []
    Info: (1x1 struct)
        orders: 1 double
```

4.1.2 info method

```
info(Gh)
Gh.info()
Gh.info(Key, Value, ...)
```

Description

Gh.info()

print informations on class fields with 3 levels of recursivity (i.e. field of field of field).

Gh.info(Key, Value, ...)

specifies function options using one or more **Key,Value** pair arguments. The **Key** options can be

- **'maxlevel'** : level of recursivity, default is 3.
- **'tab'** : number of space characters between two levels of recursivity, default is 4.

Matlab code with output

```
meshfile=fc_oogmsh.gmsh.buildmesh2d('condenser',6,'verbose',0,'force',true);
Gh = fc_oogmsh.oogmsh4(meshfile);
Gh.info('maxlevel',2);
```

```
[fc-oogmsh] Using gmsh 4.5.1 to write MSH file format version 4.1 in <fc-oogmsh>/meshes/condenser-6.msh
fc_oogmsh.oogmsh4 with properties:
[1] q : [2 3041] double
[1] nq : [1 1] double
[1] dim : [1 1] double
[1] d : [1 1] double
[1] toGlobal : [1 3041] double
[1] meshfile : [1 109] char
[1] partitionnedfile : [1 1] logical
[1] MeshFormat : [1 1] struct
[2] version : [1 3] char
[2] file_type : [1 1] double
[2] data_size : [1 1] double
[1] PhysicalNames : [0 0] double
[1] Entities : [1 1] struct
[2] numPoints : [1 1] double
[2] Points : [1 11] struct
[2] numCurves : [1 1] double
[2] Curves : [1 10] struct
[2] numSurfaces : [1 1] double
[2] Surfaces : [1 1] struct
[2] numVolumes : [1 1] double
[2] Volumes : [1 0] struct
[1] PartitionedEntities : [0 0] double
[1] Nodes : [1 1] struct
[2] numEntityBlocks : [1 1] double
[2] numNodes : [1 1] double
[2] minNodeTag : [1 1] double
[2] maxNodeTag : [1 1] double
[2] EntityBlocks : [1 21] struct
[1] Elements : [1 1] struct
[2] numEntityBlocks : [1 1] double
[2] numElements : [1 1] double
[2] minElementTag : [1 1] double
[2] maxElementTag : [1 1] double
[2] EntityBlocks : [1 19] struct
[2] ElementTypes : [1 19] double
[1] PeriodicLinks : [0 0] double
[1] Info : [1 1] struct
[2] meshfile : [1 109] char
[1] orders : [1 1] double
```

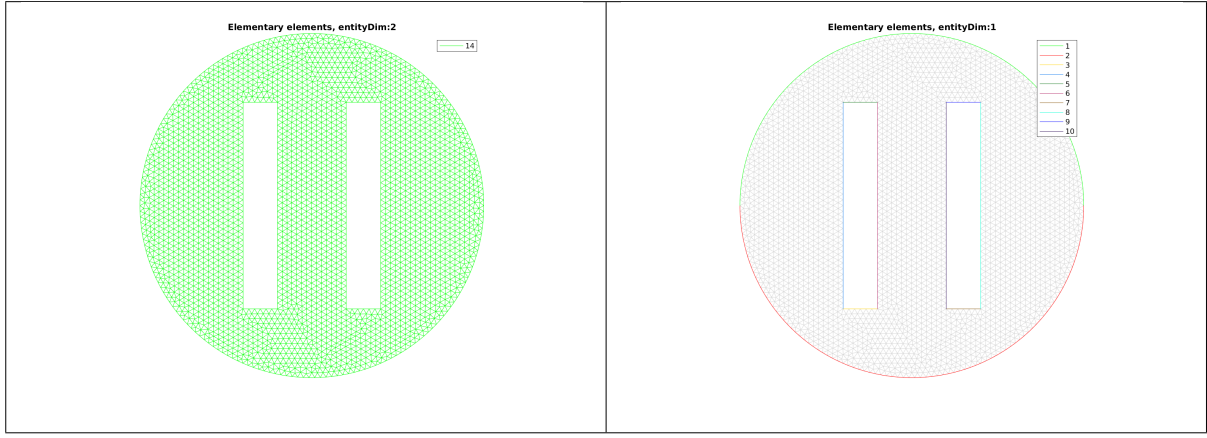


Figure 1: *Elementary Tag* elements of the *geofile condenser.geo*

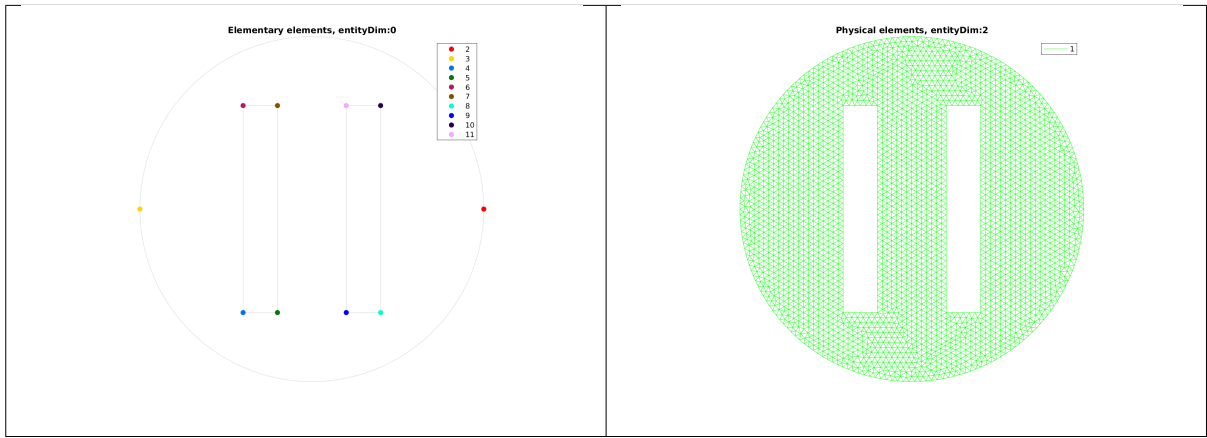


Figure 2: *Physical Tag* elements of the *geofile condenser.geo*

In the *geofile condenser.geo* the *Physical Tags* are created from the *Elementary Tags* as follow

```
...
Physical Line(1) = {1, 2};
Physical Line(98) = {5, 6, 3, 4};
Physical Line(99) = {9, 8, 7, 10};
Physical Surface(1) = {14};
```

4.1.3 `get_ElementaryTags` method

```
eltags=get_ElementaryTags(Gh,ElType)
eltags=Gh.get_ElementaryTags(ElType)
```

Description

```
eltags=Gh.get_ElementaryTags(ElType)
```

returns all the elementary tags associated with elements of type `ElType` as an array with unique elements. `ElType` is described in section ?? . For example, `ElType` is 1 for 2-nodes `line` (i.e 1-simplex of order 1), `ElType` is 2 for 3-nodes `triangle` (i.e 2-simplex of order 1) and `ElType` is 4 for 4-nodes `tetrahedron` (i.e 3-simplex of order 1).

Matlab code with output

```
eltags1=Gh.get_ElementaryTags(1)
eltags2=Gh.get_ElementaryTags(2)
```

```
eltags1 =
    1    2    3    4    5    6    7    8    9   10

eltags2 =
    14
```

4.1.4 `get_PhysicalTags` method

```
phtags=get_PhysicalTags(Gh,EltType)
phtags=Gh.get_PhysicalTags(EltType)
```

Description

```
phtags=Gh.get_PhysicalTags(EltType)
```

returns all the elementary tags associated with elements of type `EltType` as an array with unique elements.

Matlab code with output

```
phtags1=Gh.get_PhysicalTags(1)
phtags2=Gh.get_PhysicalTags(2)
```

```
phtags1 =
    1   98   99

phtags2 =
    1
```

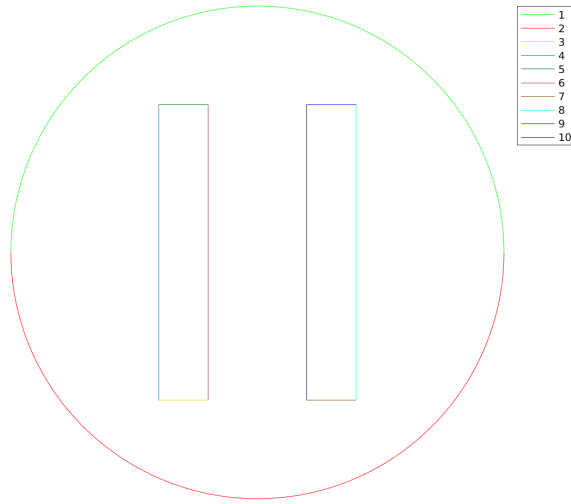
4.1.5 `get_me_ElementaryTag` method

```
me=get_me_ElementaryTag(Gh,EltType,EltTag)
me=Gh.get_me_ElementaryTag(EltType,EltTag)
```

Description

```
me=Gh.get_me_ElementaryTag(EltType,EltTag)
```

returns `me` the connectivity array of mesh elements of type and *elementary tag* given respectively by `EltType` and `EltTag`. This array is associated with the `Gh.q` nodes/vertices array.



```
meshfile=fc_oogmsh.gmsh.buildmesh2d('condenser',6, 'verbose',0);
Gh = fc_oogmsh.ooGmsh4(meshfile);
eltags1=Gh.get_ElementaryTags(1);
n1=length(eltags1);
colors = fc_tools.graphics.selectColors(length(eltags1));
figure(1)
hold on
for i=1:n1
    me=Gh.get_me_ElementaryTag(1,eltags1(i));
    h(i)=fc_graphics4mesh.plotmesh(Gh.q,me,'color',colors(i,:));
    clegend{i}=num2str(eltags1(i));
end
legend(h,clegend, 'Location', 'NorthEastOutside', 'AutoUpdate', 'off');
axis image;axis off
fc_tools.graphics.SaveAllFigsAsFiles('ooGmsh4_get_me_ElementaryTags', SaveOptions{:})
```

Listing 1: Plot curves mesh elements by using `get_me_ElementaryTags` function

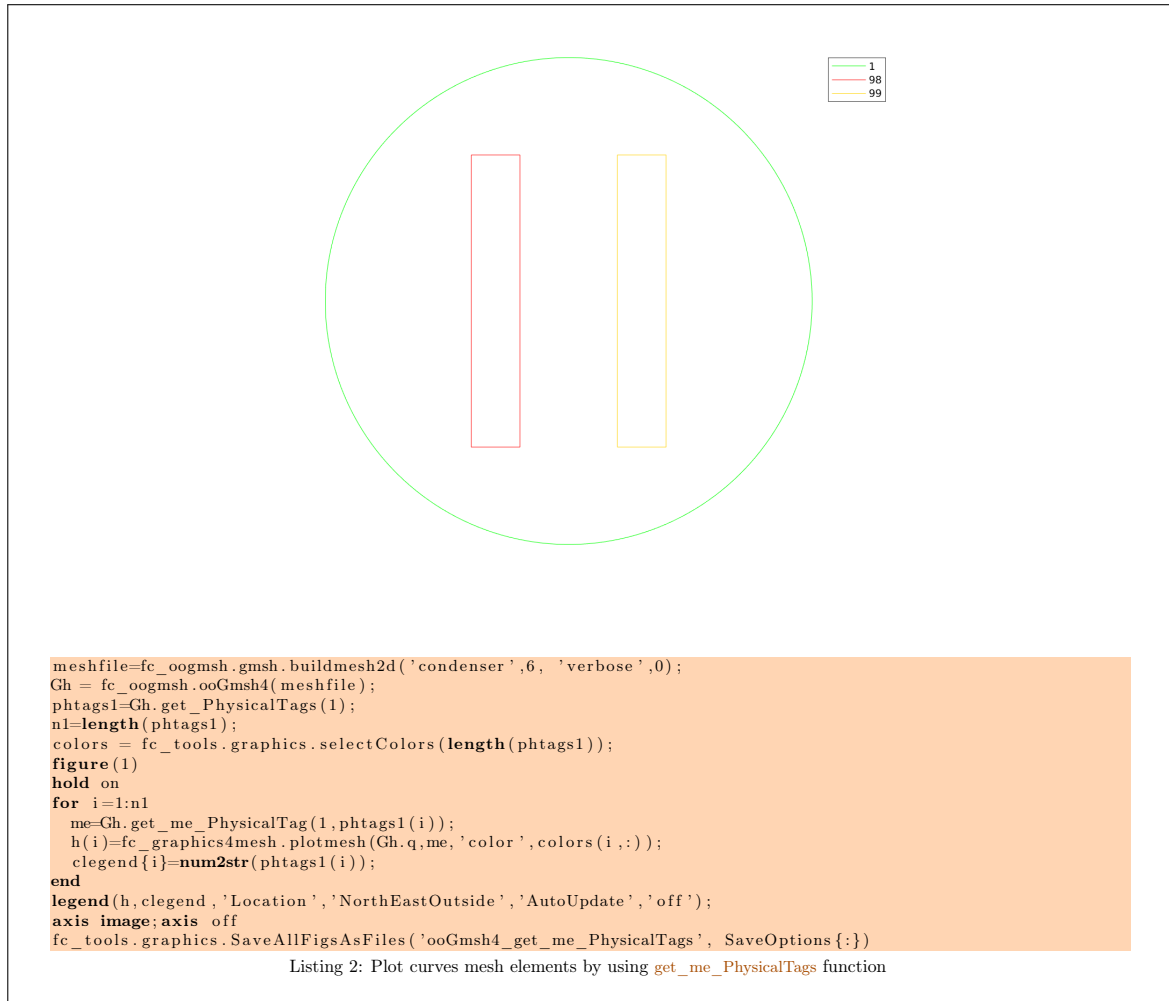
4.1.6 `get_me_PhysicalTag` method

```
me=get_me_PhysicalTag(Gh,EltType,PhyTag)
me=Gh.get_me_PhysicalTag(EltType,PhyTag)
```

Description

`get_me_PhysicalTag(Gh,EltType,PhyTag)`

returns `me` the connectivity array of mesh elements of type and *physical tag* given respectively by `EltType` and `PhyTag`. This array is associated with the `Gh.q` nodes/vertices array.



4.1.7 `get_localmesh_ElementaryTag` method

```

[q,me]=Gh.get_localmesh_ElementaryTag(EltType,EltTag)
[q,me,toGlobal]=Gh.get_localmesh_ElementaryTag(EltType,EltTag)

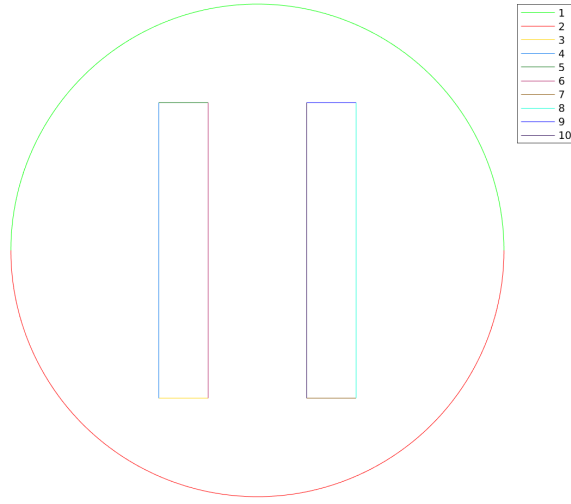
```

```
[q,me]=Gh.get_localmesh_ElementaryTag(EltType,EltTag)
```

returns the *local* nodes/vertices array `q` and the *local* connectivity array `me` of the element of type `EltType` and with *elementary tag* given by `EltTag`.

```
[q,me,toGlobal]=Gh.get_localmesh_ElementaryTag(EltType,EltTag)
```

Also returns the *global* tags array `toGlobal` such that `Gh.q(:,toGlobal)` is equal to `q`.



```

meshfile=fc_oogmsh.gmsh.buildmesh2d('condenser',6, 'verbose',0);
Gh = fc_oogmsh.ooGmsh4(meshfile);
eltags1=Gh.get_ElementaryTags(1); % 1: 2-nodes line
n1=length(eltags1);
colors = fc_tools.graphics.selectColors(length(eltags1));
figure(1)
hold on
for i=1:n1
    [q,me]=Gh.get_localmesh_ElementaryTag(1,eltags1(i));
    h(i)=fc_graphics4mesh.plotmesh(q,me,'color',colors(i,:));
    clegend{i}=num2str(eltags1(i));
end
legend(h,clegend, 'Location', 'NorthEastOutside', 'AutoUpdate', 'off');
axis image;axis off
fc_tools.graphics.SaveAllFigsAsFiles('ooGmsh4_get_localmesh_ElementaryTag', SaveOptions{:})

```

Listing 3: Plot 2-nodes line mesh elements by using `get_localmesh_ElementaryTag` function

4.1.8 `get_localmesh_PhysicalTag` method

```

[q,me]=Gh.get_localmesh_PhysicalTag(EltType,PhyTag)
[q,me,toGlobal]=Gh.get_localmesh_PhysicalTag(EltType,PhysicalTag)

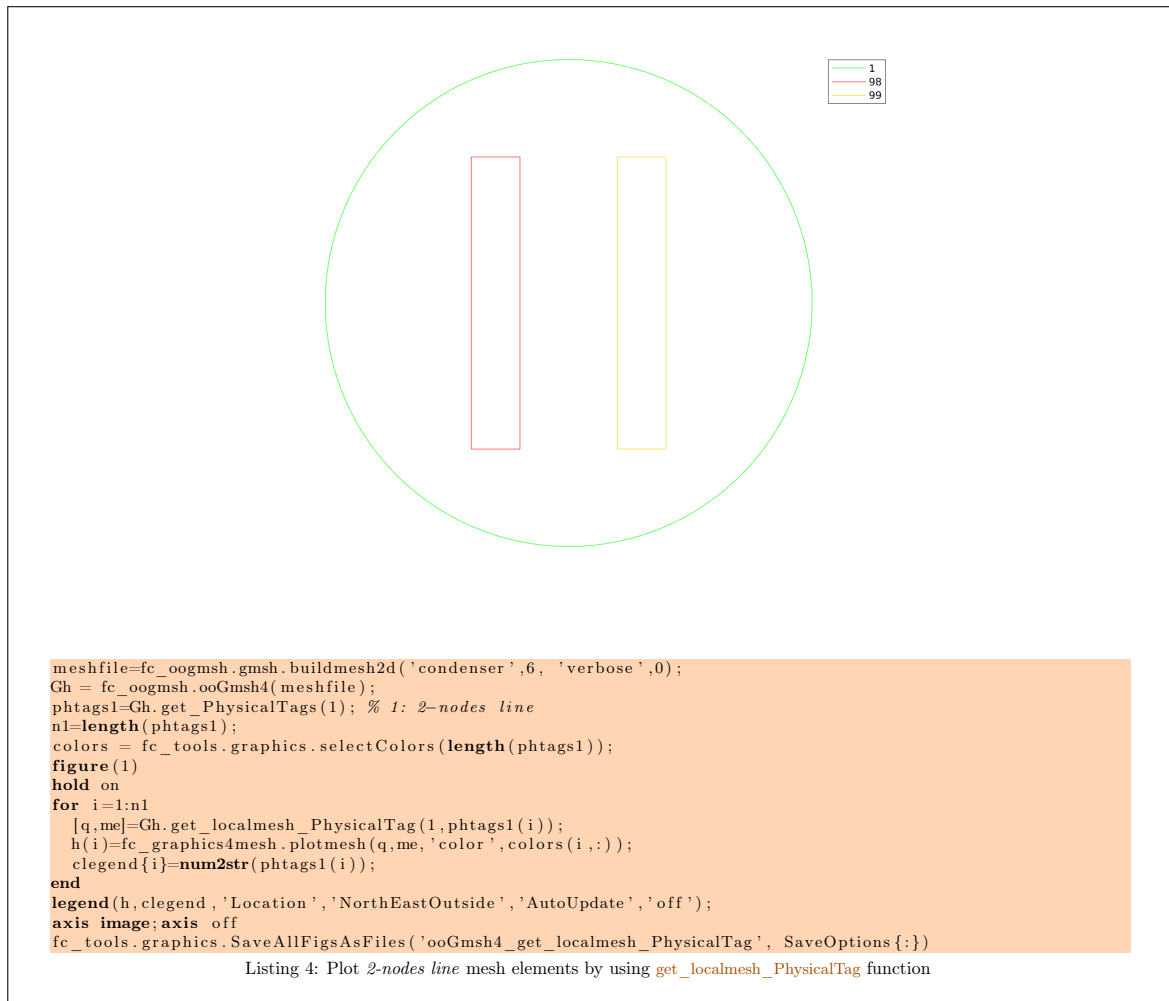
```

```
[q,me]=Gh.get_localmesh_PhysicalTag(EltType,PhyTag)
```

returns the *local* nodes/vertices array `q` and the *local* connectivity array `me` of the elements of type `EltType` and with `PhyTag` given by `PhysicalTag`.

```
[q,me,toGlobal]=Gh.get_localmesh_PhysicalTag(EltType,PhyTag)
```

Also returns the *global* tags array `toGlobal` such that `Gh.q(:,toGlobal)` is equal to `q`.



4.2 Description of properties

Fields of **MeshFormat** structure

version	: string, version of the mesh file format.
file_type	: integer, 0 for ASCII mode, 1 for binary mode.
data_size	: integer, <code>sizeof(size_t)</code>

Fields of the (optional) **PhysicalName** structure

dimension	: integer.
physicalTag	: integer.
name	: string

Fields of the **Entities** structure

numPoints	: integer.
Points	: array of Point structure.
numCurves	: integer.
Curves	: array of Curve structure.
numSurfaces	: integer.
Surfaces	: array of Surface structure.
numVolumes	: integer.
Volumes	: array of Volume structure.

Fields of (optional) **PartitionedEntities** structure

numPartitions	: integer.
numGhostEntities	: integer.
GhostEntities	: array of structure.
numPoints	: integer
Points	: array of structure.
numCurves	: integer
Curves	: array of structure.
numSurfaces	: integer
Surfaces	: array of structure.
numVolumes	: integer.
Volumes	: array of structure.

Fields of **Nodes** structure

numEntityBlocks	: integer.
numNodes	: integer.
minNodeTag	: integer.
maxNodeTag	: integer
EntityBlocks	: array of EntityBlock structure.

Fields of **EntityBlocks** structure of **Nodes**

entityDim	: integer.
entityTag	: integer.
parametric	: integer.
numNodes	: integer.
nodeTags	: 1-by-numNodes array of integer.
Nodes	: 3-by-numNodes array of double.

Fields of **Elements** structure

numEntityBlocks	: integer.
numElements	: integer.
minElementTag	: integer.
maxElementTag	: integer
EntityBlocks	: array of EntityBlock structure.
ElementTypes	: array of .

Fields of **EntityBlocks** structure of **Elements**

entityDim	:	integer.
entityTag	:	integer.
elementType	:	integer.
elementDesc	:	structure returned by function <code>gmsh.elm_type_desc(elementType)</code> .
numElementsBlock	:	integer.
nodeTags	:	n -by- numElementsBlock array. n depends of elementType : $n =$ <code>elementDesc.nb_nodes</code>
elementTags	:	1-by- numElementsBlock array

Fields of **PeriodicLink**

entityDim	:	integer.
entityTag	:	integer.
entityTagMaster	:	integer.
numAffine	:	
values	:	.
numCorrespondingNodes	:	.
nodeTags	:	
nodeTagMasters	:	

4.3 Sample 1

The 2d .geo file *condenser.geo* is used to create a .msh file : *condenser-25.msh*. This .msh file contains only 1 (2-node line) and 2 (3-node triangle) *elm-type*.

Matlab code with output

```
meshfile=fc_oogmsh.gmsh.buildmesh('condenser',25,'verbose',0,'force',true);  
Gh = fc_oogmsh.ooGmsh4(meshfile)
```

```
[fc-oogmsh] Using gmsh 4.5.1 to write MSH file format version 4.1 in <fc-oogmsh>/meshes/condenser-25.msh  
Gh =  
fc_oogmsh.ooGmsh4 with properties:  
  q: (2x49238 double)  
  nq: 49238 double  
  dim: 2 double  
  d: 2 double  
  toGlobal: (1x49238 double)  
  meshfile: (1x110 char)  
  partitionedfile: 0 logical  
  MeshFormat: (1x1 struct)  
  PhysicalNames: []  
  Entities: (1x1 struct)  
  PartitionedEntities: []  
  Nodes: (1x1 struct)  
  Elements: (1x1 struct)  
  PeriodicLinks: []  
  Info: (1x1 struct)  
  orders: 1 double
```

4.4 Sample 2

The 3d .geo file *cylinderkey.geo* is used to create a .msh file : *cylinderkey-10.msh*. This .msh file contains 1 (2-node line), 2 (3-node triangle) and 4 (4-node tetrahedron) *elm-type*.

Matlab code with output

```
meshfile=fc_oogmsh.gmsh.buildmesh3d('cylinderkey',10, ...  
    'verbose',0,'force',true);  
Gh = fc_oogmsh.ooGmsh4(meshfile)
```

```
[fc-oogmsh] Using gmsh 4.5.1 to write MSH file format version 4.1 in <fc-oogmsh>/meshes/cylinderkey-10.msh
```

```
Gh =
```

```
fc_oogmsh.ooGmsh4 with properties:  
    q: (3x5834 double)  
    nq: 5834 double  
    dim: 3 double  
    d: 3 double  
    toGlobal: (1x5834 double)  
    meshfile: (1x112 char)  
    partitionedfile: 0 logical  
    MeshFormat: (1x1 struct)  
    PhysicalNames: []  
    Entities: (1x1 struct)  
    PartitionedEntities: []  
    Nodes: (1x1 struct)  
    Elements: (1x1 struct)  
    PeriodicLinks: []  
    Info: (1x1 struct)  
    orders: 1 double
```

4.5 Sample 3

The 3d .geo file *ball8.geo* is used to create a 3d surface .msh file : *ball8-50.msh*. This .msh file contains 1 (2-node line), 2 (3-node triangle) and 15 (1-node point) *elm-type*.

Matlab code with output

```
meshfile=fc_oogmsh.gmsh.buildmesh3ds('ball8',50, 'verbose',0,'force',true);  
Gh = fc_oogmsh.ooGmsh4(meshfile)
```

```
[fc-oogmsh] Using gmsh 4.5.1 to write MSH file format version 4.1 in <fc-oogmsh>/meshes/ball8-50.msh
```

```
Gh =
```

```
fc_oogmsh.ooGmsh4 with properties:  
    q: (3x37801 double)  
    nq: 37801 double  
    dim: 3 double  
    d: 3 double  
    toGlobal: (1x37801 double)  
    meshfile: (1x106 char)  
    partitionedfile: 0 logical  
    MeshFormat: (1x1 struct)  
    PhysicalNames: []  
    Entities: (1x1 struct)  
    PartitionedEntities: []  
    Nodes: (1x1 struct)  
    Elements: (1x1 struct)  
    PeriodicLinks: []  
    Info: (1x1 struct)  
    orders: 1 double
```

5 ooGmsh2 class (version 2.2)

The `ooGMSH2` class can be used to read `gmsh` mesh files with the MSH ASCII file format (version 2.2) described for example in [3], section 9.1. A MSH file can contain various mesh elements which are identified by an *elm-type* integer given in Appendix A. One can also refer to the `fc_oogmsh.gmsh.elm_type_desc` function, described in Appendix B.1, to obtain information on a given *elm-type*.

When reading a MSH file (format 2.2) generated by `gmsh`, we split the mesh elements by *elm-type* and generate an array of `Elmt` structure. The dimension of this array is the number of different *elm-type* founds on the .msh file.

The `Elmt` structure is given by

Fields of **Elmt** structure

type	: integer, refers to the type of the element : 1 for 2-node line, 2 for 3-node triangle, ... See the <i>elm-type</i> description of [3], section 9.1. Informations on a given type can be obtained by using <code>elt=fc_oogmsh.gmsh.elm_type_desc(type)</code> .
geo	: string, contains the kind of geometry: 'line', 'triangle', 'tetrahedron', ...
d	: integer, space dimension or d -simplex.
order	: integer, order of the element.
nme	: integer, number of mesh elements.
me	: array of nb_nodes -by- nme integers, connectivity array. nb_nodes is equal to <code>elt.nb_nodes</code> where <code>elt=fc_oogmsh.gmsh.elm_type_desc(type)</code> .
phys_lab	: array of nme -by-... integers, physical labels of the elements.
geo_lab	: array of nme -by-... integers, geometrical labels of the elements.
nb_parts	: array of nme -by-1 integers, number of mesh partitions to which the element belongs.
part_lab	: array of nme -by-max(nb_parts) integers, <code>part_lab(i, 1 : nb_parts(i))</code> contains all the partitions index to which the <i>i</i> -th element belongs.

The **ooGMSH2** class was created to store a maximum of(all the) information(s) contained in the .msh file. The properties of this class are:

Properties of **ooGMSH** class

dim	: integer space dimension
nq	: integer number of vertices/nodes
q	: dim-by-n _q array of reals array of vertex coordinates
types	: array of integers List of the element types found in the mesh file.
orders	: array of integers List of the orders of the element types found in the mesh file.
sElts	: array of Elmt structure One Elmt structure by element type, such that <code>sElts(i)</code> contains all the elements of type <code>types(i)</code> and order <code>orders(i)</code> .

5.1 Methods

5.1.1 **ooGmsh2** constructor

The **ooGmsh2** class have only one constructor :

```
Gh=fc_oogmsh.ooGmsh2( meshfile )
```

where meshfile is the name of ... a mesh file

Matlab code with output

```
fprintf( '1)\_Building\_the\_mesh\n' )
meshfile=fc_oogmsh.gmsh.buildmesh2d( 'disk3holes',15, ...
    'verbose',0, 'force',true, 'MshFileVersion','2.2' );
fprintf( '2)\_Reading\_the\_mesh\n' );
Gh = fc_oogmsh.ooGmsh2( meshfile );
fprintf( '→\_Gh\_is\_an\_ooGmsh2\_object\_containing\_a\_MSH\_file\_version\_...
    %s\n',Gh.MeshFormat.version )
fprintf( '3)\_Displaying\_Gh\n' );
Gh
```

```
1) Building the mesh
[fc-oogmsh] Using gmsh 4.5.1 to write MSH file format version 2.2 in <fc-oogmsh>/meshes/disk3holes-15.msh
2) Reading the mesh
→ Gh is an ooGmsh2 object containing a MSH file version 2.2
3) Displaying Gh

Gh =

fc_oogmsh.ooGmsh2 with properties:
    q: (2x910 double)
    dim: 2 double
    ng: 910 double
    d: 2 double
    sElts: (2x1 struct)
    toGlobal: (1x910 double)
    partitionnedfile: 0 logical
    orders: 1 double
    types: [ 1 2 ] (1x2 int32)
    MeshFormat: (1x1 struct)
    meshfile: (1x11 char)
    Info: (1x1 struct)
    debug: (1x1 struct)
```

5.1.2 info method

```
info(Gh)
Gh.info()
Gh.info(Key, Value, ...)
```

Description

Gh.info()

print informations on class fields with 3 levels of recursivity (i.e. field of field of field).

Gh.info(Key, Value, ...)

specifies function options using one or more **Key,Value** pair arguments. The **Key** options can be

- **'maxlevel'** : level of recursivity, default is 3.
- **'tab'** : number of space characters between two levels of recursivity, default is 4.

Matlab code with output

```
meshfile=fc_oogmsh.gmsh.buildmesh2d('disk3holes',15, ...
    'verbose',0,'force',true,'MshFileVersion','2.2');
Gh = fc_oogmsh.oogmsh2(meshfile);
Gh.info('maxlevel',2);
```

```
[fc-oogmsh] Using gmsh 4.5.1 to write MSH file format version 2.2 in <fc-oogmsh>/meshes/disk3holes-15.msh
fc_oogmsh.oogmsh2 with properties:
[1] q : [2 910] double
[1] dim : [1 1] double
[1] nq : [1 1] double
[1] d : [1 1] double
[1] sElts : [2 1] struct
[2] type : [1 1] int32
[2] geo : [1 4] char
[2] d : [1 1] double
[2] order : [1 1] double
[2] me : [2 146] double
[2] nme : [1 1] double
[2] phys_lab : [146 1] double
[2] geo_lab : [146 1] double
[2] part_lab : [0 0] double
[2] nb_parts : [146 1] double
[1] toGlobal : [1 910] double
[1] partitionnedfile : [1 1] logical
[1] orders : [1 1] double
[1] types : [1 2] int32
[1] MeshFormat : [1 1] struct
[2] version : [1 3] char
[2] file_type : [1 1] double
[2] data_size : [1 1] double
[1] meshfile : [1 111] char
[1] Info : [1 1] struct
[2] meshfile : [1 111] char
[1] debug : [1 1] struct
[2] Mt : [1824 55] int32
```

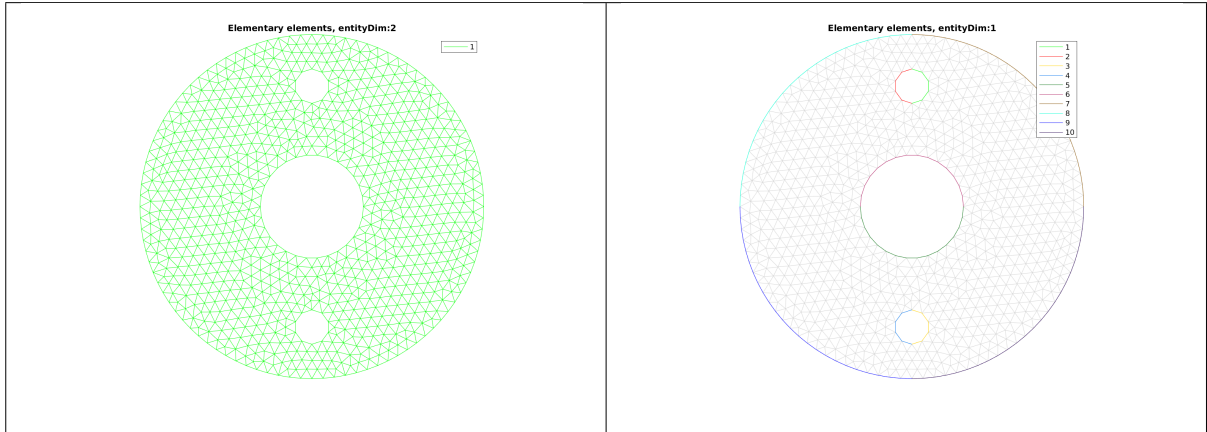


Figure 3: *Elementary Tag* elements of the *geofile disk3holes.geo*

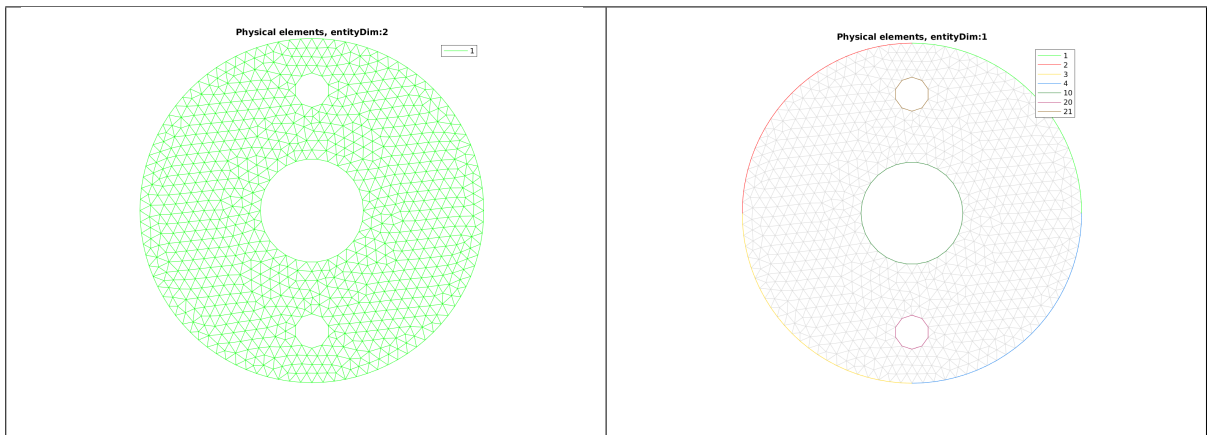


Figure 4: *Physical Tag* elements of the *geofile disk3holes.geo*

In the *geofile disk3holes.geo* the *Physical Tags* are created from the *Elementary Tags* as follow

```
...
Physical Line(10) = {6, 5};
Physical Line(21) = {2, 1};
Physical Line(20) = {4, 3};
Physical Line(1) = {7};
Physical Line(2) = {8};
Physical Line(3) = {9};
Physical Line(4) = {10};
Physical Surface(1) = {1};
```

5.1.3 `get_ElementaryTags` method

```
eltags=get_ElementaryTags(Gh,EltType)
eltags=Gh.get_ElementaryTags(EltType)
```

Description

```
eltags=Gh.get_ElementaryTags(EltType)
```

returns all the elementary tags associated with elements of type `EltType` as an array with unique elements. `EltType` is described in Section A. For example, `EltType` is 1 for 2-nodes `line` (i.e 1-simplex of order 1), `EltType` is 2 for 3-nodes `triangle` (i.e 2-simplex of order 1) and `EltType` is 4 for 4-nodes `tetrahedron` (i.e 3-simplex of order 1).

Matlab code with output

```
eltags1=Gh.get_ElementaryTags(1)
eltags2=Gh.get_ElementaryTags(2)
```

```
[fc-oogmsh] Using gmsh 4.5.1 to write MSH file format version 2.2 in <fc-oogmsh>/meshes/disk3holes-15.msh

eltags1 =
     1     2     3     4     5     6     7     8     9    10

eltags2 =
     1
```

5.1.4 `get_PhysicalTags` method

```
phtags=get_PhysicalTags(Gh,EltType)
phtags=Gh.get_PhysicalTags(EltType)
```

Description

```
phtags=Gh.get_PhysicalTags(EltType)
```

returns all the physical tags associated with elements of type `EltType` as an array with unique elements. `EltType` is described in Section A.

Matlab code with output

```
phtags1=Gh.get_PhysicalTags(1)
phtags2=Gh.get_PhysicalTags(2)
```

```
[fc-oogmsh] Using gmsh 4.5.1 to write MSH file format version 2.2 in <fc-oogmsh>/meshes/disk3holes-15.msh

phtags1 =
     1     2     3     4    10    20    21

phtags2 =
     1
```

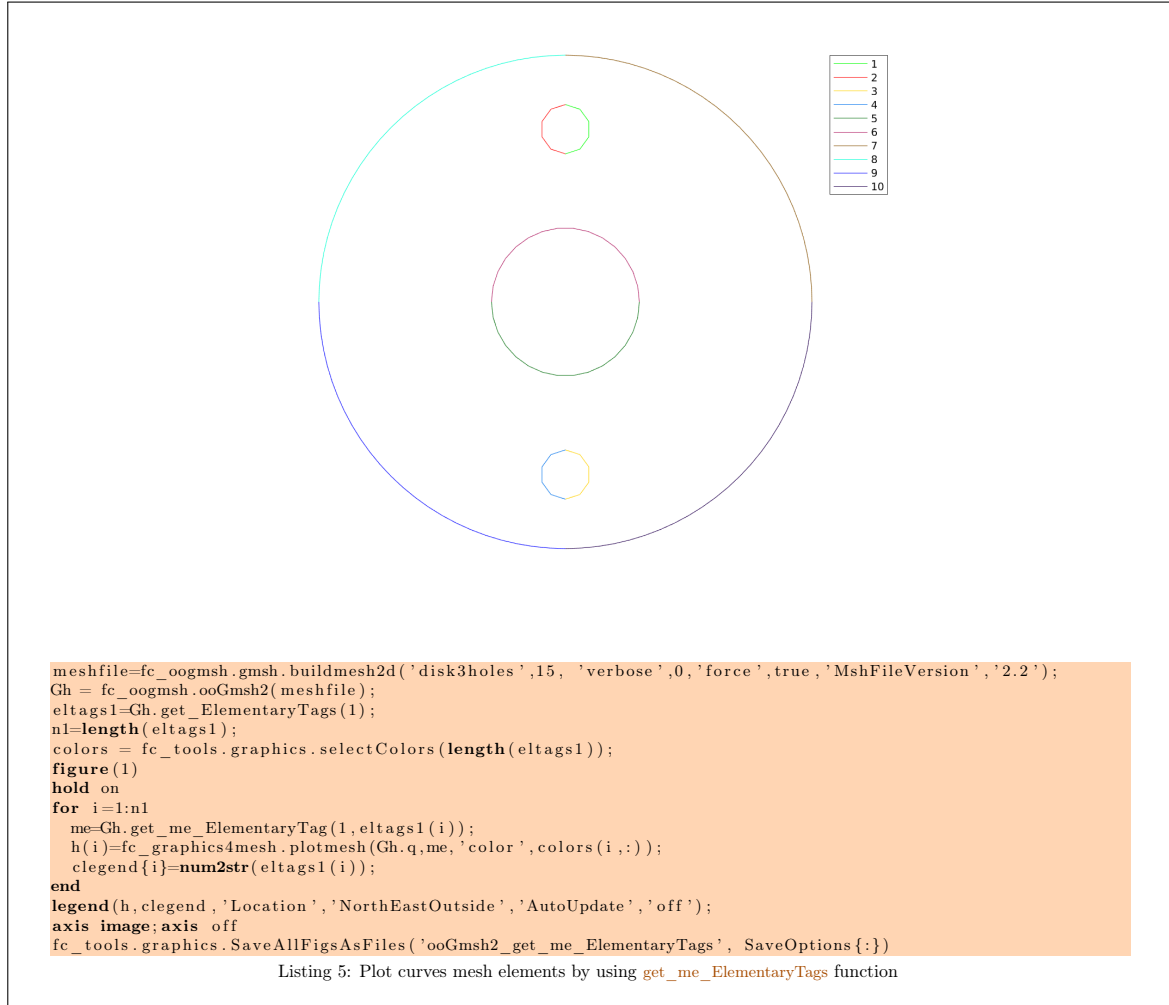
5.1.5 `get_me_ElementaryTag` method

```
me=get_me_ElementaryTag(Gh,EltType,EltTag)
me=Gh.get_me_ElementaryTag(EltType,EltTag)
```

Description

```
me=Gh.get_me_ElementaryTag(EltType,EltTag)
```

returns `me` the connectivity array of mesh elements of type and *elementary tag* given respectively by `EltType` and `EltTag`. This array is associated with the `Gh.q` nodes/vertices array.



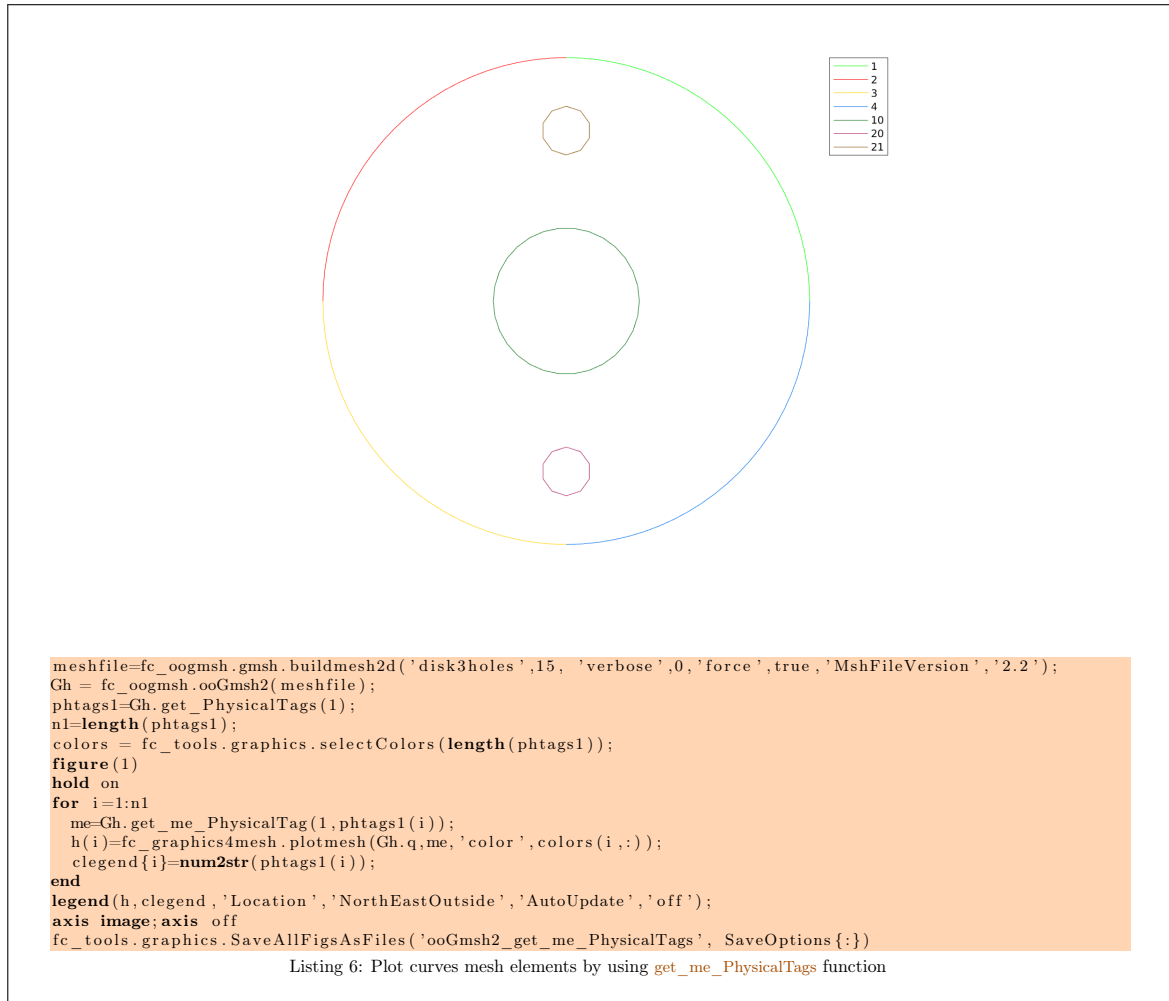
5.1.6 `get_me_PhysicalTag` method

```
me=get_me_PhysicalTag(Gh,EltType,PhysicalTag)
me=Gh.get_me_PhysicalTag(EltType,PhysicalTag)
```

Description

```
get_me_PhysicalTag(Gh,EltType,PhysicalTag)
```

returns `me` the connectivity array of mesh elements of type and *physical tag* given respectively by `EltType` and `PhysicalTag`.



5.1.7 `get_localmesh_ElementaryTag` method

```

[q,me]=Gh.get_localmesh_ElementaryTag(EltType,EltTag)
[q,me,toGlobal]=Gh.get_localmesh_ElementaryTag(EltType,EltTag)

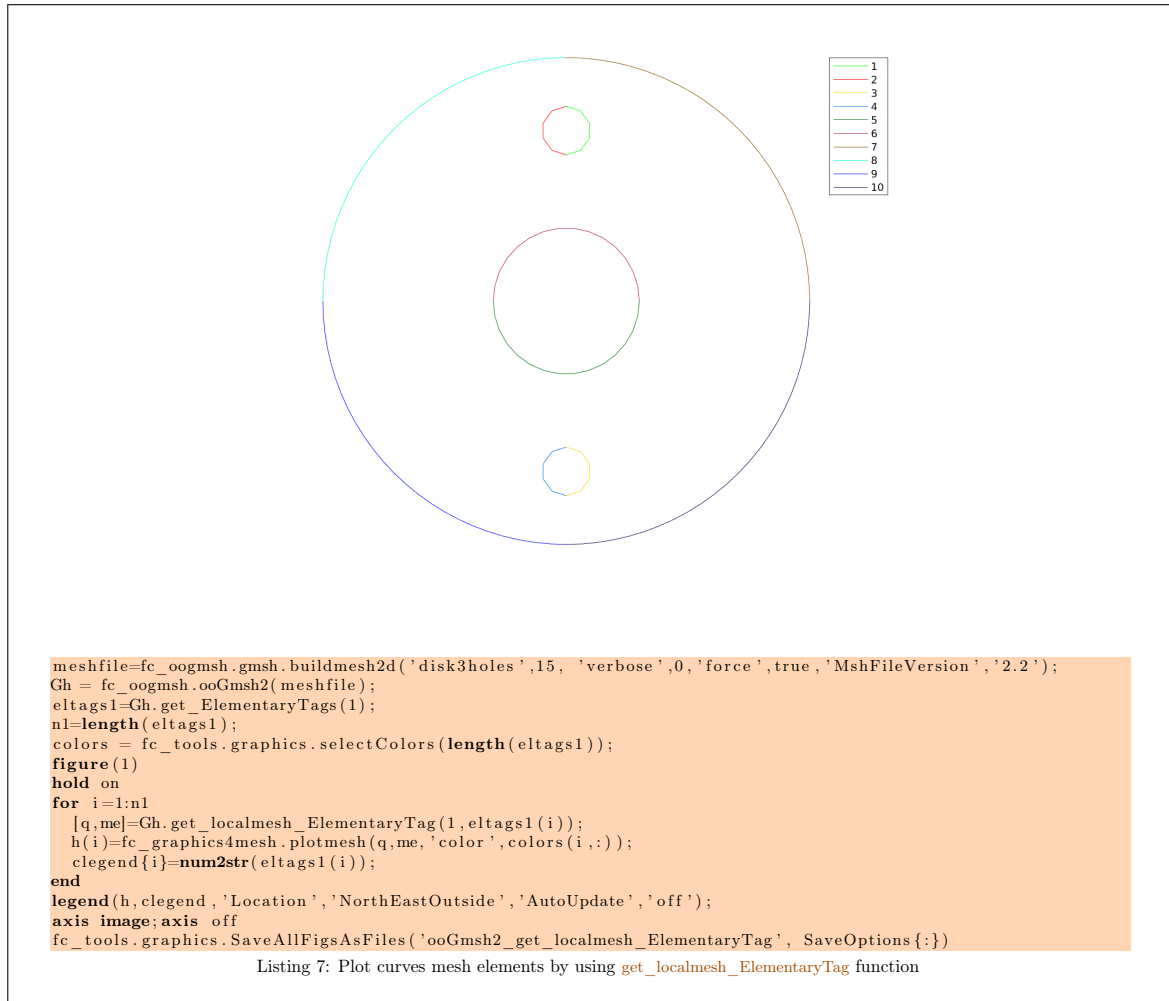
```

```
[q,me]=Gh.get_localmesh_ElementaryTag(EltType,EltTag)
```

returns the *local* nodes/vertices array `q` and the *local* connectivity array `me` of the element of type `EltType` and with *elementary tag* given by `EltTag`.

```
[q,me,toGlobal]=Gh.get_localmesh_ElementaryTag(EltType,EltTag)
```

Also returns the *global* tags array `toGlobal` such that `Gh.q(:,toGlobal)` is equal to `q`.



5.1.8 `get_localmesh_PhysicalTag` method

```

[q,me]=Gh.get_localmesh_PhysicalTag(EltType,PhysicalTag)
[q,me,toGlobal]=Gh.get_localmesh_PhysicalTag(EltType,PhysicalTag)

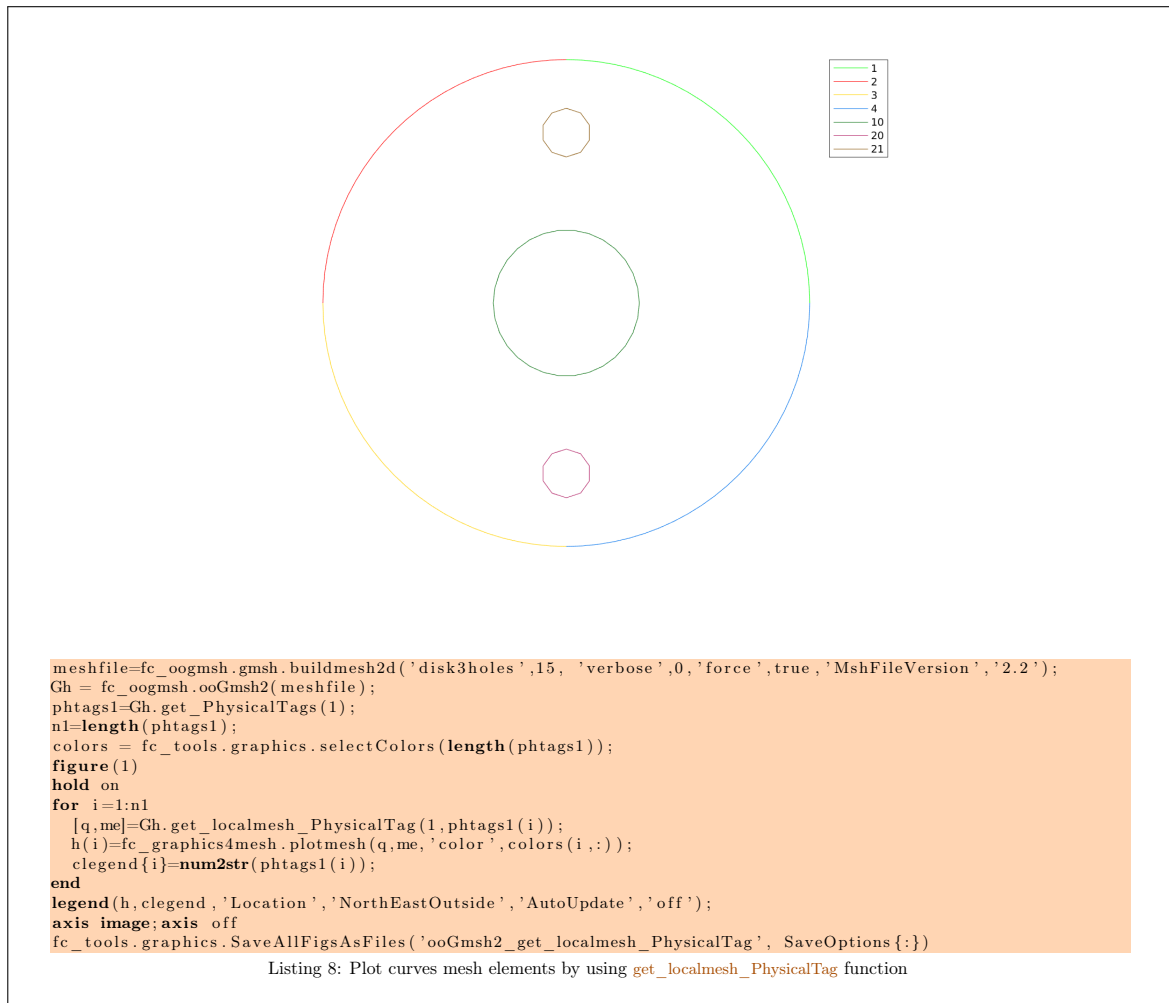
```

```
[q,me]=Gh.get_localmesh_PhysicalTag(EltType,PhysicalTag)
```

returns the *local* nodes/vertices array `q` and the *local* connectivity array `me` of the elements of type `EltType` and with *PhysicalTag* given by `PhysicalTag`.

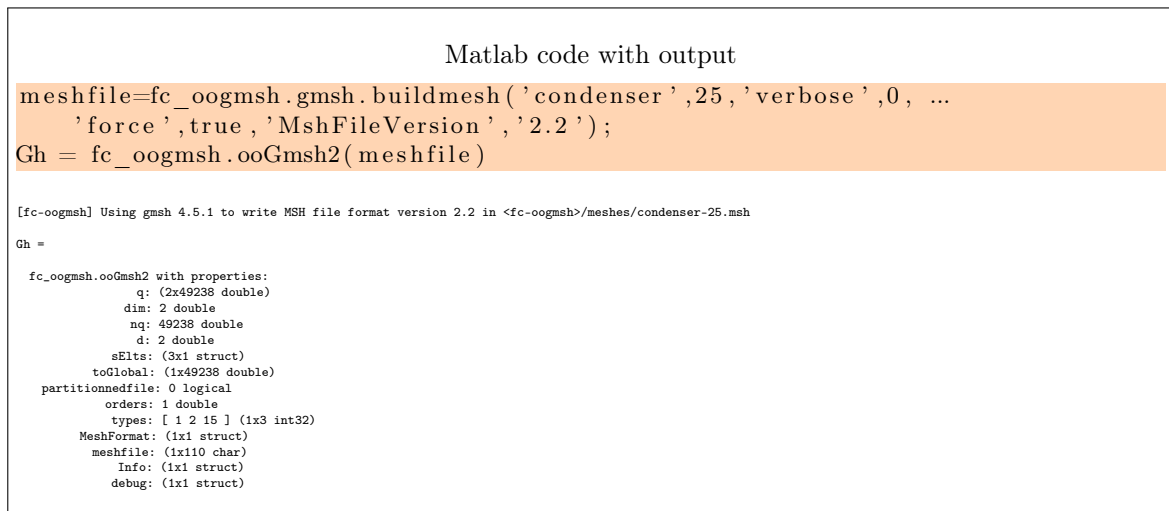
```
[q,me,toGlobal]=Gh.get_localmesh_PhysicalTag(EltType,PhysicalTag)
```

Also returns the *global* tags array `toGlobal` such that `Gh.q(:,toGlobal)` is equal to `q`.



5.2 Sample 1

The 2d .geo file *condenser.geo* is used to create a .msh file : *condenser-25.msh*. This .msh file contains only 1 (2-node line) and 2 (3-node triangle) *elm-type*.



5.3 Sample 2

The 3d .geo file *cylinderkey.geo* is used to create a .msh file : *cylinderkey-10.msh*. This .msh file contains 1 (2-node line), 2 (3-node triangle) and 4 (4-node tetrahedron) *elm-type*.

Matlab code with output

```
meshfile=fc_oogmsh.gmsh.buildmesh3d('cylinderkey',10,'verbose',0, ...
    'force',true,'MshFileVersion','2.2');
Gh = fc_oogmsh.ooGmsh2(meshfile)
```

```
[fc-oogmsh] Using gmsh 4.5.1 to write MSH file format version 2.2 in <fc-oogmsh>/meshes/cylinderkey-10.msh
```

```
Gh =
```

```
fc_oogmsh.ooGmsh2 with properties:
    q: (3x5834 double)
    dim: 3 double
    nq: 5834 double
    d: 3 double
    sElts: (3x1 struct)
    toGlobal: (1x5834 double)
    partitionnedfile: 0 logical
    orders: 1 double
    types: [ 1 2 4 ] (1x3 int32)
    MeshFormat: (1x1 struct)
    meshfile: (1x12 char)
    Info: (1x1 struct)
    debug: (1x1 struct)
```

5.4 Sample 3

The 3d .geo file *ball8.geo* is used to create a 3d surface .msh file : *ball8-50.msh*. This .msh file contains 1 (2-node line), 2 (3-node triangle) and 15 (1-node point) *elm-type*.

Matlab code with output

```
meshfile=fc_oogmsh.gmsh.buildmesh3ds('ball8',50,'verbose',0, ...
    'force',true,'MshFileVersion','2.2');
Gh = fc_oogmsh.ooGmsh2(meshfile)
```

```
[fc-oogmsh] Using gmsh 4.5.1 to write MSH file format version 2.2 in <fc-oogmsh>/meshes/ball8-50.msh
```

```
Gh =
```

```
fc_oogmsh.ooGmsh2 with properties:
    q: (3x37801 double)
    dim: 3 double
    nq: 37801 double
    d: 2 double
    sElts: (3x1 struct)
    toGlobal: (1x37801 double)
    partitionnedfile: 0 logical
    orders: 1 double
    types: [ 1 2 15 ] (1x3 int32)
    MeshFormat: (1x1 struct)
    meshfile: (1x106 char)
    Info: (1x1 struct)
    debug: (1x1 struct)
```

A Element type

In a .msh file the kind of mesh elements are identified by their *elm-type* integer values :

<i>elm-type</i>	description
1	2-node line
2	3-node triangle
3	4-node quadrangle
4	4-node tetrahedron
5	8-node hexahedron
6	6-node prism
7	5-node pyramid
8	3-node second order line (2 nodes associated with the vertices and 1 with the edge)
9	6-node second order triangle (3 nodes associated with the vertices and 3 with the edges)
10	9-node second order quadrangle (4 nodes associated with the vertices, 4 with the edges and 1 with the face)

11	10-node second order tetrahedron (4 nodes associated with the vertices and 6 with the edges)
12	27-node second order hexahedron (8 nodes associated with the vertices, 12 with the edges, 6 with the faces and 1 with the volume)
13	18-node second order prism (6 nodes associated with the vertices, 9 with the edges and 3 with the quadrangular faces)
14	14-node second order pyramid (5 nodes associated with the vertices, 8 with the edges and 1 with the quadrangular face)
15	1-node point
16	8-node second order quadrangle (4 nodes associated with the vertices and 4 with the edges)
17	20-node second order hexahedron (8 nodes associated with the vertices and 12 with the edges)
18	15-node second order prism (6 nodes associated with the vertices and 9 with the edges)
19	13-node second order pyramid (5 nodes associated with the vertices and 8 with the edges)
20	9-node third order incomplete triangle (3 nodes associated with the vertices, 6 with the edges)
21	10-node third order triangle (3 nodes associated with the vertices, 6 with the edges, 1 with the face)
22	12-node fourth order incomplete triangle (3 nodes associated with the vertices, 9 with the edges)
23	15-node fourth order triangle (3 nodes associated with the vertices, 9 with the edges, 3 with the face)
24	15-node fifth order incomplete triangle (3 nodes associated with the vertices, 12 with the edges)
25	21-node fifth order complete triangle (3 nodes associated with the vertices, 12 with the edges, 6 with the face)
26	4-node third order edge (2 nodes associated with the vertices, 2 internal to the edge)
27	5-node fourth order edge (2 nodes associated with the vertices, 3 internal to the edge)
28	6-node fifth order edge (2 nodes associated with the vertices, 4 internal to the edge)
29	20-node third order tetrahedron (4 nodes associated with the vertices, 12 with the edges, 4 with the faces)
30	35-node fourth order tetrahedron (4 nodes associated with the vertices, 18 with the edges, 12 with the faces, 1 in the volume)
31	56-node fifth order tetrahedron (4 nodes associated with the vertices, 24 with the edges, 24 with the faces, 4 in the volume)
92	64-node third order hexahedron (8 nodes associated with the vertices, 24 with the edges, 24 with the faces, 8 in the volume)
93	125-node fourth order hexahedron (8 nodes associated with the vertices, 36 with the edges, 54 with the faces, 27 in the volume)

B Other functions

B.1 function `fc_oogmsh.gmsh.elm_type_desc`

This function returns a structure which contains some informations on a `gmsh elt-type` described in Appendix A.

Syntaxe

```
elt=fc_oogmsh.gmsh.elm_type_desc(type)
```

Matlab code with output

```
elt2=fc_oogmsh.gmsh.elm_type_desc(2)
elt4=fc_oogmsh.gmsh.elm_type_desc(4)
elt11=fc_oogmsh.gmsh.elm_type_desc(11)

elt2 =

struct with fields:

    define: 'MSH_TRI_3'
    elm_type: 2
    desc: '3-node triangle'
    nb_nodes: 3
    order: 1
    incomplete: 0
    d: 2
    geo: 'triangle'

elt4 =

struct with fields:

    define: 'MSH_TET_4'
    elm_type: 4
    desc: '4-node tetrahedron'
    nb_nodes: 4
    order: 1
    incomplete: 0
    d: 3
    geo: 'tetrahedron'

elt11 =

struct with fields:

    define: 'MSH_TET_10'
    elm_type: 11
    desc: '10-node second order tetrahedron (4 nodes associated with the vertices and 6 with the edges)'
    nb_nodes: 10
    order: 2
    incomplete: 0
    d: 3
    geo: 'tetrahedron'
```

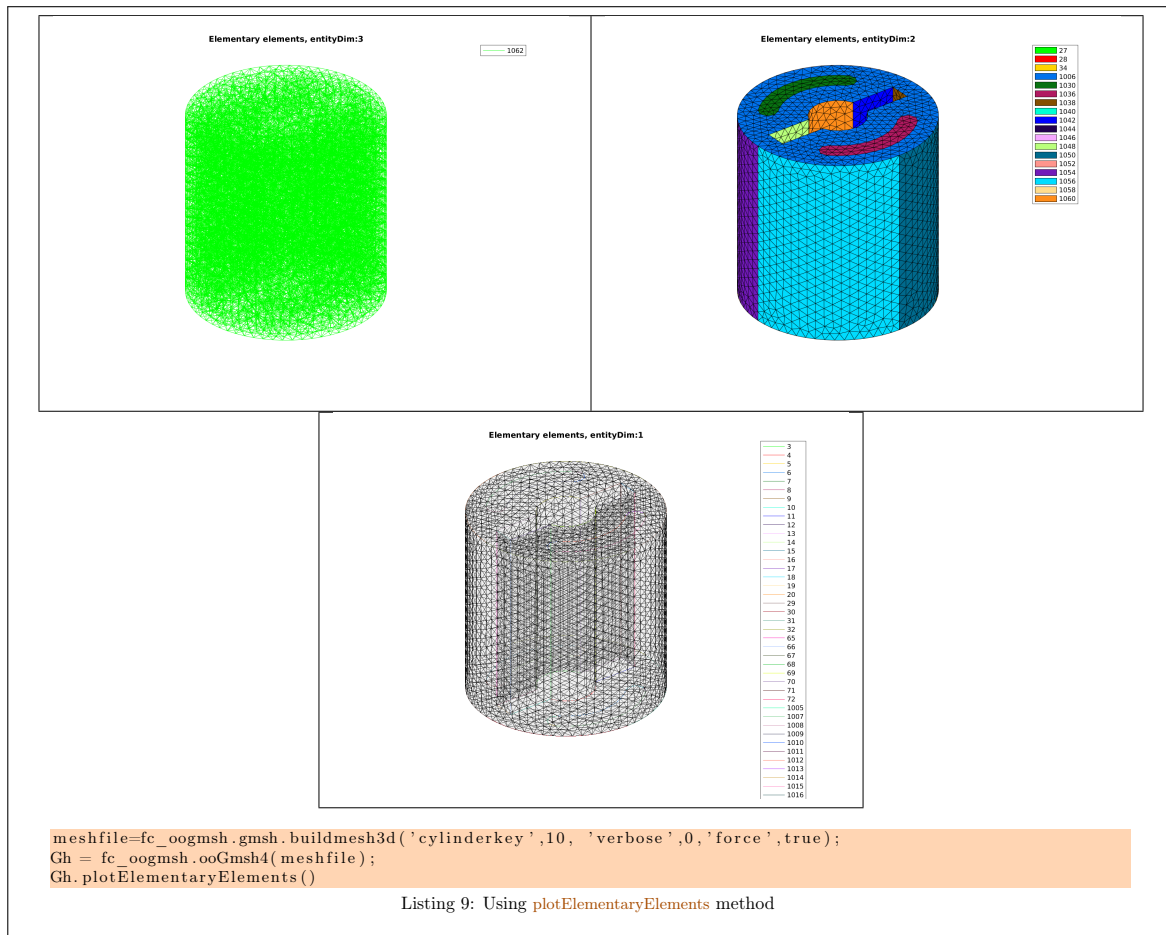
B.2 method `plotElementaryElements`

This function plot *Elementary Elements* of an `ooGmsh2` or `ooGmsh4` object of *Element Type*

- 1, *2-node line* elements,
- 2, *3-node triangle* elements,
- 4, *4-node tetrahedron* elements.

This function uses the `fc-graphics4mesh` toolbox [1] version 0.1.1.

```
Gh.plotElementaryElements()
plotElementaryElements(Gh)
```



B.3 method `plotPhysicalElements`

This function plot *Physical Tags* of an `ooGmsh2` or `ooGmsh4` object of *Element Type*

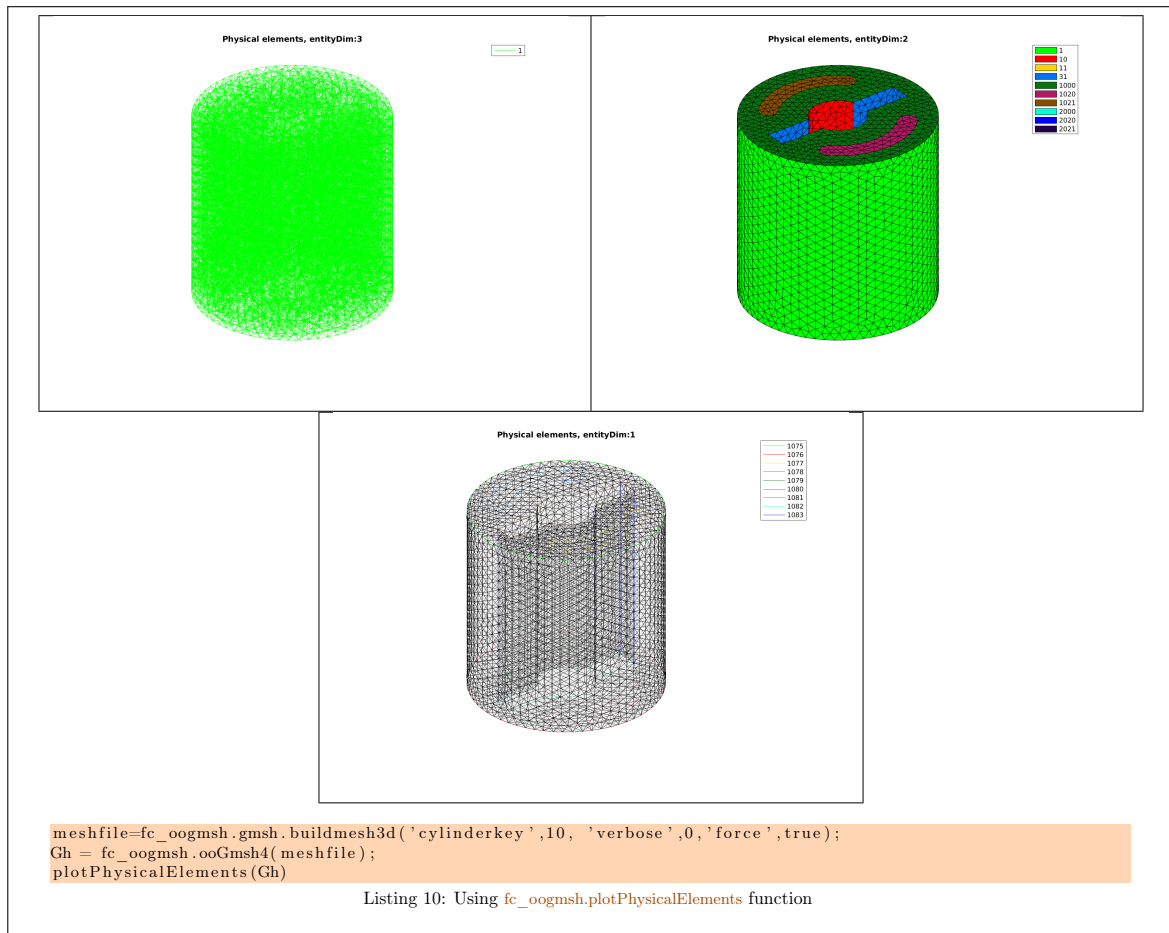
- 1, 2-node line elements,
- 2, 3-node triangle elements,
- 4, 4-node tetrahedron elements.

This function uses the `fc-graphics4mesh` toolbox [1] version 0.1.1.

```

Gh.plotPhysicalElements()
plotPhysicalElements(Gh)

```



B.4 method `plotPartitionElements`

This function can be used with partitioned mesh file built with one of the following functions:

```

fc_oogmsh.gmsh.buildpartmesh3d,
fc_oogmsh.gmsh.buildpartmesh3ds,
fc_oogmsh.gmsh.buildpartmesh2d.

```

This function plot *Partition Tags* of an `ooGmsh2` or `ooGmsh4` object of *Element Type*

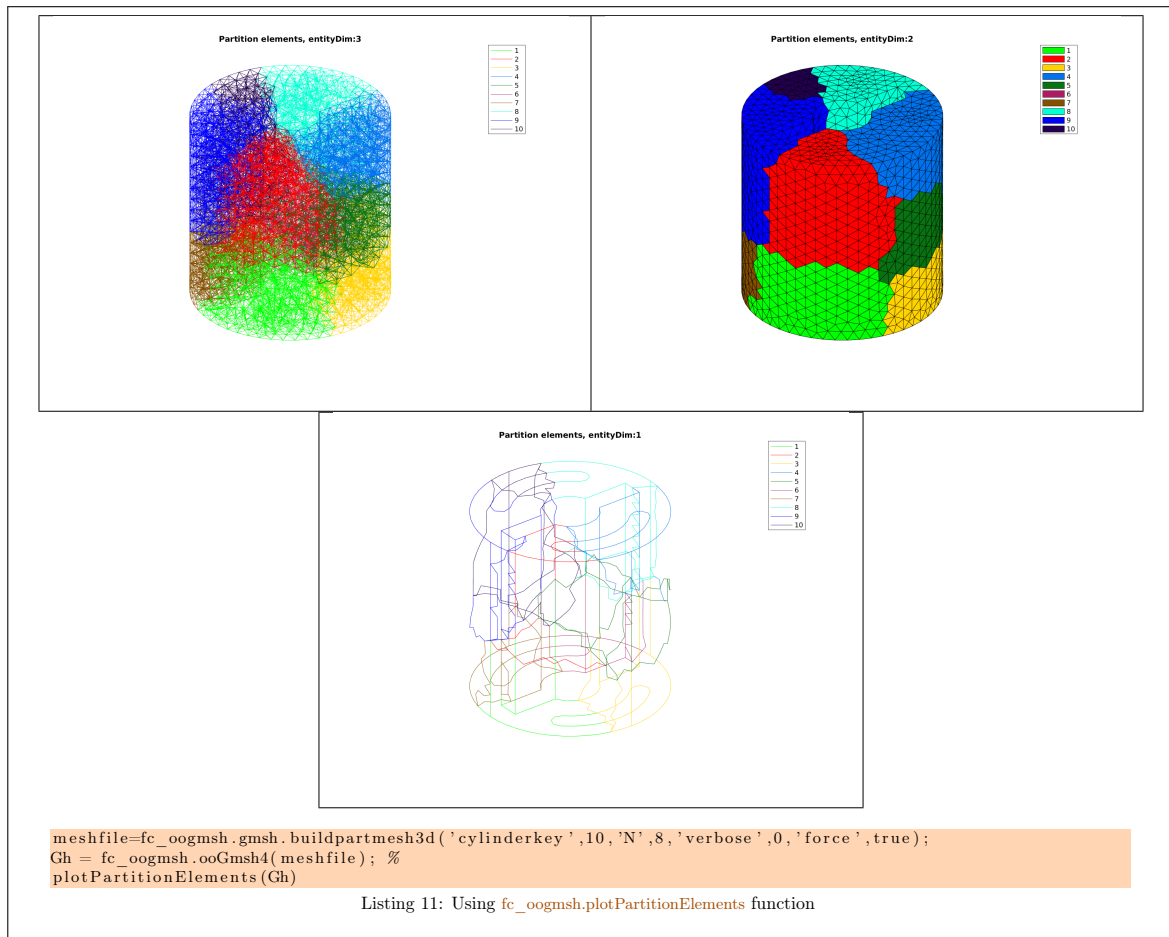
- 1, *2-node line* elements,
- 2, *3-node triangle* elements,
- 4, *4-node tetrahedron* elements.

This function uses the `fc-graphics4mesh` toolbox [1] version 0.1.1.

```

Gh.plotPartitionElements()
plotPartitionElements(Gh)

```



B.5 method `plotInterfaceElements`

This function can be used with partitioned mesh file built with one of the following functions:

```

fc_oogmsh.gmsh.buildpartmesh3d,
fc_oogmsh.gmsh.buildpartmesh3ds,
fc_oogmsh.gmsh.buildpartmesh2d.

```

This function plot *Interface Tags* of the interfaces between partitions of an `ooGmsh2` or `ooGmsh4` object of *Element Type*

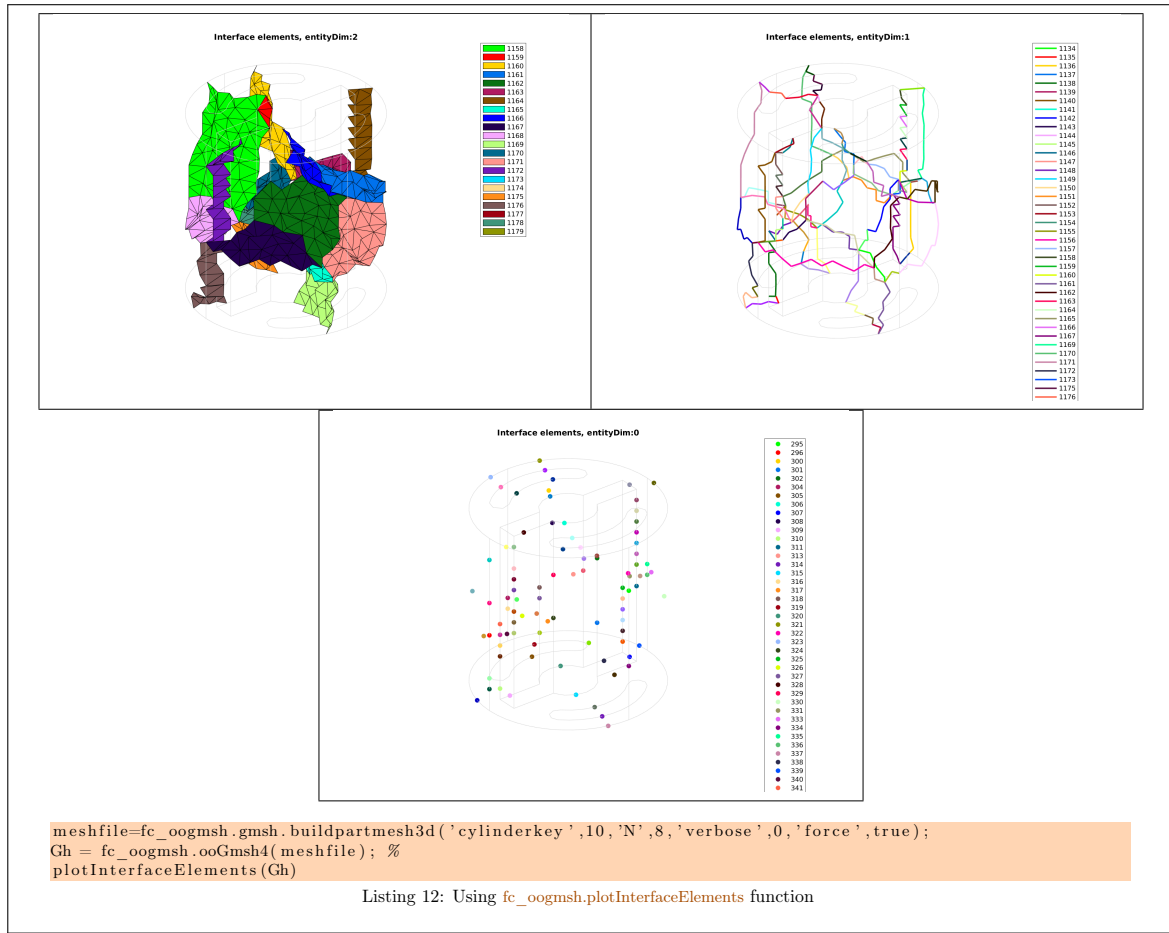
- 1, 2-node *line* elements,
- 2, 3-node *triangle* elements,
- 4, 4-node *tetrahedron* elements.

This function uses the `fc-graphics4mesh` toolbox [1] version 0.1.1.

```

Gh.plotInterfaceElements()
plotInterfaceElements(Gh)

```



B References

- [1] F. Cuvelier. `fc_graphics4mesh`: a Matlab toolbox for displaying simplices meshes or datas on simplices meshes. <http://www.math.univ-paris13.fr/~cuvelier/software/>, 2017. User's Guide.
- [2] C. Geuzaine and J.-F. Remacle. Gmsh: A 3-D finite element mesh generator with built-in pre- and post-processing facilities. *International Journal for Numerical Methods in Engineering*, 79(11):1309–1331, 2009.
- [3] C. Geuzaine and J.-F. Remacle. Gmsh 2.15.0. <http://gmsh.info>, 2016.
- [4] C. Geuzaine and J.-F. Remacle. Gmsh 4.2.1. <http://gmsh.info>, 2019.

Informations for git maintainers of the oogmsh Matlab toolbox

git informations on the toolboxes used to build this manual

```
-----
name : fc-oogmsh
tag : 0.2.2
commit : 90fc9826fea6eb8dd66afc3a58677564c8f7f442
date : 2020-02-17
time : 13-31-05
status : 0
-----
name : fc-tools
tag : 0.0.30
commit : 773f018c72144189f34c69cef3b4e8f0adac4b25
date : 2020-02-15
time : 09-39-43
status : 0
-----
name : fc-bench
tag : 0.1.2
commit : 666dc60d1277f5fa9c99dee4ae1c33270f22c57d
date : 2020-02-16
time : 06-38-46
status : 0
-----
name : fc-amat
tag : 0.1.2
commit : 957340f6e71d805dbd8b9d04c434b24fd3f92591
date : 2020-02-16
time : 06-39-42
status : 0
-----
name : fc-meshtools
tag : 0.1.3
commit : cdbc41bc98af4e4facc1746024aced1f21aae53
date : 2020-02-17
time : 10-52-56
status : 0
-----
name : fc-graphics4mesh
tag : 0.1.1
commit : 94fbc0760793424515d9cb7b3c0d552c49682d7e
date : 2020-02-17
time : 11-05-19
status : 0
-----
```

git informations on the L^AT_EX package used to build this manual

```
-----
name : fctools
tag :
commit : 57968c4a96c2593cccc9da9efd3e52b2ff012cb5
date : 2020-02-07
time : 06:41:09
status : 1
-----
```

Using the remote configuration repository:

```
url      ssh://lagagit/MCS/Cuvelier/Matlab/fc-config
commit   5c83c4d79816e51c5f85c2c16df8f93b701c5f96
```