



# User's Guide\*

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## Abstract

This Matlab toolbox uses a **siMESH** object, coming from the **FC-SIMESH** toolbox, to display simplicial meshes or datas on simplicial meshes. Its kernel uses the **FC-GRAPHICS4MESH** toolbox.

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## 1 Introduction

This **experimental** Matlab toolbox uses the Simplicial meshes could be:

- a triangular mesh in dimension 2, made with 2-simplices (ie. triangles),
- a tetrahedral mesh in dimension 3, made with 3-simplices (ie. tetrahedron),
- a triangular mesh in dimension 3 (surface mesh), made with 2-simplices,
- a line mesh in dimension 2 or 3 made with 1-simplices (ie. lines).

A simplicial mesh is given by its vertices array `q` and its connectivity array `me`. For demonstration purpose, some simplicial meshes are given in this package. They can be load by using the function `getMesh2D`, `getMesh3D` or `getMesh3Ds` of the `fc_graphics4mesh` package.

This toolbox was tested under

**Windows 10:** with Matlab R2015b to R2017b (opengl hardware mode with NVIDIA driver 376.84 on a Quadro K600)

**MacOS Sierra:** with Matlab R2015b to R2017b (opengl hardware mode with Intel driver 10.2.37 on a HD 3000)

**Ubuntu 14.04.5 LTS:** with Matlab R2015b to R2017b (opengl hardware mode with NVIDIA driver 340.104 on a Quadro K600)

**Ubuntu 16.04 LTS:** with Matlab R2015b, R2017b (opengl hardware mode), R2016a to R2017a (opengl software mode)

## 2 Installation

### 2.1 Installation automatic, all in one (recommanded)

For this method, one just have to get/download the install file

`mfc_siplt_install.m`

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

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

```
>> cd ~/Matlab/toolboxes
>> mfc_siplt_install
```

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

```

Parts of the Matlab <fc-siplt> toolbox.
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*****
Downloading and installing the toolbox
<fc-simesh>[0.2.0]
*****
Parts of the Matlab <fc-simesh> toolbox.
Copyright (C) 2016-2017 F. Cuvelier <cuvelier@math.univ-paris13.fr>

1- Downloading and extracting the toolboxes
-> <fc-tools>[0.0.18] ... OK
-> <fc-hypermesh>[0.0.5] ... OK
-> <fc-oogmsh>[0.0.15] ... OK
-> <fc-simesh>[0.2.0] ... OK
-> <fc-graphics4mesh>[0.0.1] ... OK
-> <fc-siplt>[0.0.1] ... OK
2- Setting the toolboxes
2-a) Setting the <fc-hypermesh> toolbox
Write in ...
/home/cuvelier/tmp/Matlab/fc-siplt-full/fc_hypermesh-0.0.5/configure_loc.m ...
...
-> done
2-b) Setting the <fc-oogmsh> toolbox
-> Using GMSH binary : /home/cuvelier/bin/gmsh
Write in ...
/home/cuvelier/tmp/Matlab/fc-siplt-full/fc_oogmsh-0.0.15/configure_loc.m ...
...
-> done
2-c) Setting the <fc-simesh> toolbox without graphics
[fc-simesh] no graphics package installed
Write in ...
/home/cuvelier/tmp/Matlab/fc-siplt-full/fc_simesh-0.2.0/configure_loc.m ...
...
-> done
2-d) Setting the <fc-graphics4mesh> toolbox
Write in ...
/home/cuvelier/tmp/Matlab/fc-siplt-full/fc_graphics4mesh-0.0.1/configure_loc.m ...
...
-> done
2-e) Setting the <fc-siplt> toolbox
[fc-simesh] No graphical toolbox installed!
Write in ...
/home/cuvelier/tmp/Matlab/fc-siplt-full/fc_siplt-0.0.1/configure_loc.m ...
...
-> done
2-f) Setting the <fc-simesh> toolbox with graphics
Write in ...
/home/cuvelier/tmp/Matlab/fc-siplt-full/fc_simesh-0.2.0/configure_loc.m ...
...
-> done
3- Using instructions
To use the <fc-simesh> toolbox:
addpath('/home/cuvelier/tmp/Matlab/fc-siplt-full/fc_simesh-0.2.0')
fc_simesh.init()

See /home/cuvelier/tmp/Matlab/mfc_simesh_set.m
<fc-simesh>[0.2.0]: installed

*** Using instructions
To use the <fc-siplt> toolbox:
addpath('/home/cuvelier/tmp/Matlab/fc-siplt-full/fc_simesh-0.2.0')
fc_simesh.init()

See /home/cuvelier/tmp/Matlab/mfc_siplt_set.m

```

The complete toolbox (i.e. with all the other needed toolboxes) is stored in the directory `~/Matlab/toolboxes/fc-siplt-full` and, for each Matlab session, one have to set the toolbox by:

```
>> addpath('~/Matlab/toolboxes/fc-siplt-full/mfc-siplt-0.0.1')
>> fc_siplt.init()
```

For **uninstalling**, one just have to delete directory

~/Matlab/toolboxes/fc-siplt-full

### 3 Mesh

The functions `getMesh2D`, `getMesh3D` and `getMesh3Ds` return a mesh vertices array `q`, a mesh elements connectivity array associated with the input argument `d` (simplex dimension) and the indices array `toGlobal`. The vertices array `q` is a  $dim$ -by- $n_q$  array where  $dim$  is the space dimension (2 or 3) and  $n_q$  the number of vertices. The connectivity array `me` is a  $(d + 1)$ -by- $n_{me}$  array where  $n_{me}$  is the number of mesh elements and  $0 \leq d \leq dim$  is the simplicial dimension:

- $d = 0$ : points,
- $d = 1$ : lines,
- $d = 2$ : triangle,
- $d = 3$ : tetrahedron.

So we can use theses functions to obtain

- 3D mesh: `getMesh3D(3)` (*main* mesh), `getMesh3D(2)`, `getMesh3D(1)`, `getMesh3D(0)`,
- 3D surface mesh: `getMesh3Ds(2)` (*main* mesh), `getMesh3Ds(1)`, `getMesh3Ds(0)`,
- 2D mesh: `getMesh2D(2)` (*main* mesh), `getMesh2D(1)`, `getMesh2D(0)`.

For example,

- `[q3,me3,toGlobal3]=fc_graphics4mesh.getMesh3D(3)` return a 3-simplicial mesh (main mesh) in space dimension  $dim = 3$ ,
- `[q2,me2,toGlobal2]=fc_graphics4mesh.getMesh3D(2)` return a 2-simplicial mesh in space dimension  $dim = 3$ .

The third output are indices of the vertices in the *main* mesh:

`q3(:,toGlobal2) == q2`

### 4 **PLOTMESH** function

The method **PLOTMESH** displays the mesh or parts of the mesh defined by an **siMESH** object.

**Syntaxe**

```
fc_siplt.plotmesh(Th,)
fc_siplt.plotmesh(Th,Name,Value,...)
```

---

## Description

`fc_siplt.plotmesh(Th,)` displays all the  $Th.d$ -dimensional simplices elements.

`fc_siplt.plotmesh(Th,Name,Value, ...)` specifies function options using one or more Name,Value pair arguments. Options of first level are

- **'d'** : to specify the dimension of the simplices elements (default :  $Th.d$ )
- **'labels'** : to select the labels of the elements to display,
- **'color'** : to specify the color of the displayed mesh elements. (default : use one color by displayed mesh elements),
- **'inlegend'** : add a legend name to graph if true (default : false)
- **'bounds'** : If true, draw the borders of the selected elementaries mesh elements (only for 2-dimensional simplices). (default : false)
- **'cutPlan'** : cut mesh by  $n$  plans given by  $n$ -by-4 array  $P$  where the equation of the  $i$ -th cut plan is given by

$$P(i,1)x + P(i,2)y + P(i,3)z + P(i,4) = 0.$$

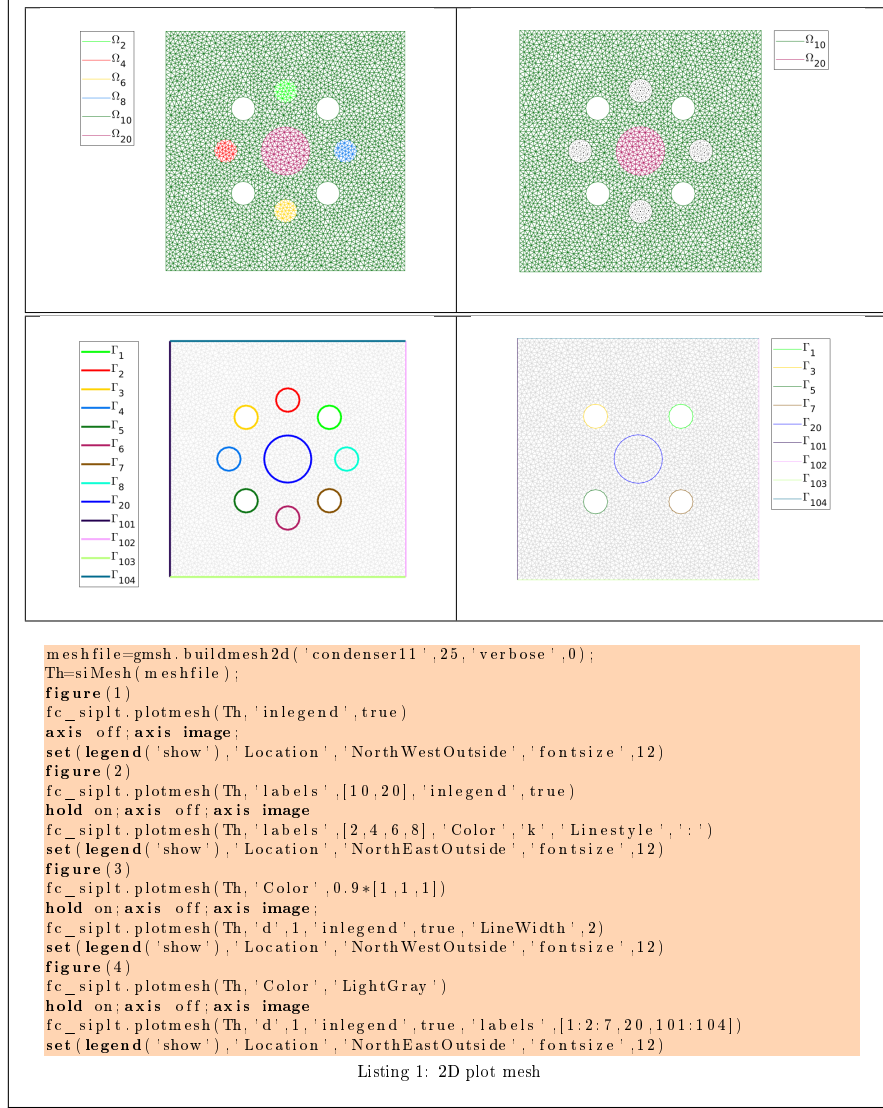
The normal vector  $P(i,1 : 3)$  pointed to the part of the mesh not displayed. (only for simplices in dimension 3) default : [] (no cut).

The options of second level depend on the type of elementaries mesh elements to represent.

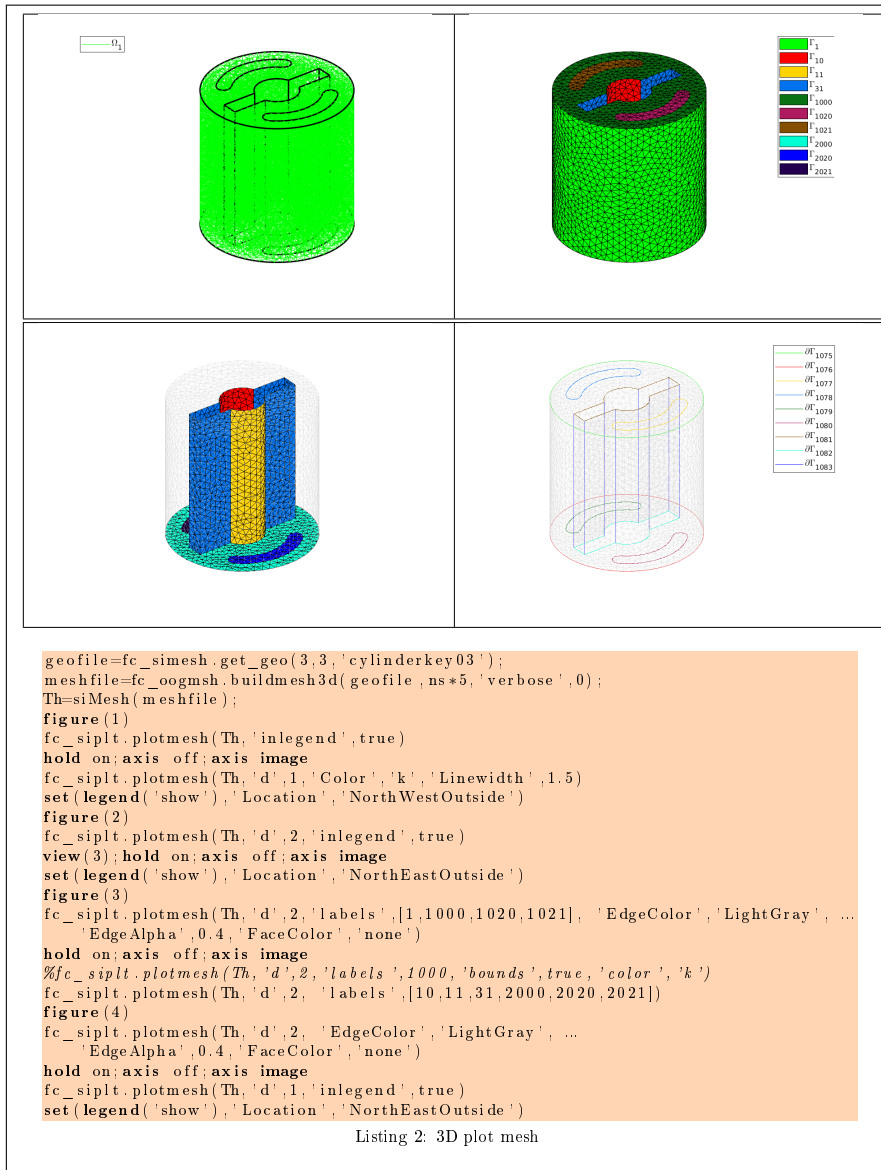
One can use any option of the following functions according to the type of  $d$ -simplex to be represented.

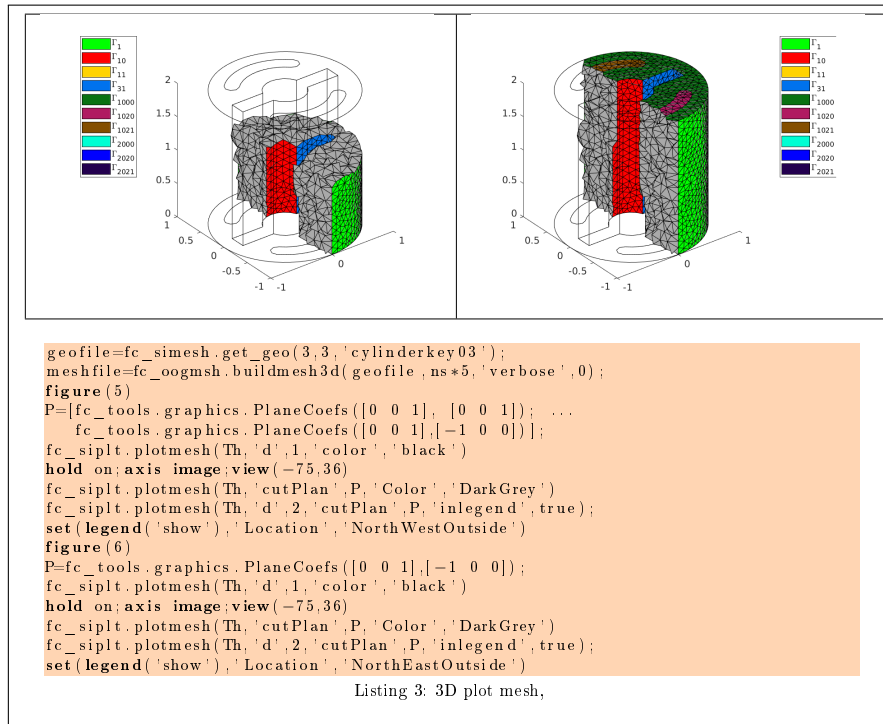
- In dimension 3,
  - if  $d == 3$ , **patch** function is used,
  - if  $d == 2$ , **trimesh** function is used,
  - if  $d == 1$ , **plot3** function is used,
  - if  $d == 0$ , **plot3** function is used,
- In dimension 2,
  - if  $d == 2$ , **trimesh** function is used,
  - if  $d == 1$ , **plot** function is used,
  - if  $d == 0$ , **plot** function is used,
- In dimension 1,
  - if  $d == 1$ , **line** function is used,
  - if  $d == 0$ , **plot** function is used,

**2D example** The following example use the *.geo* file `condenser11.geo` which is in the directory `geodir` of the toolbox ....



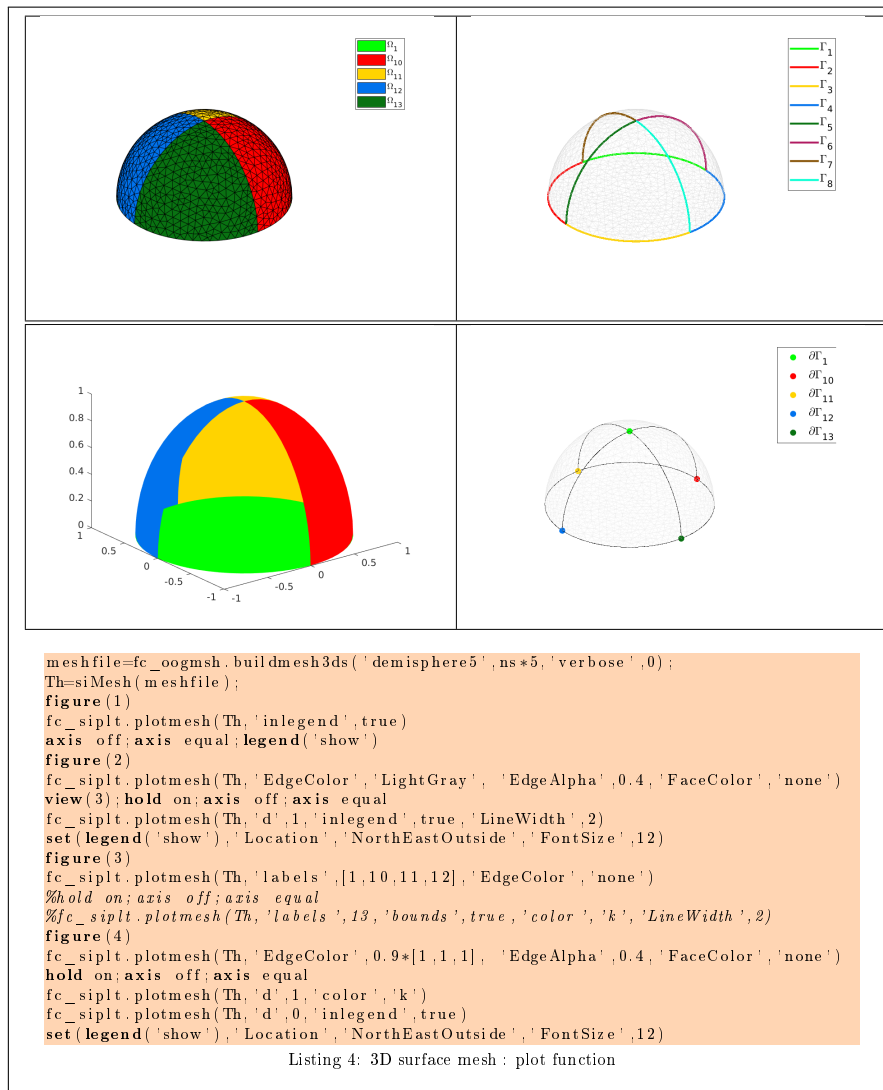
**3D example** The following example use the *.geo* file `cylinderkey.geo` which is in the directory `geodir` of the toolbox. This file contains description of a 3D mesh with simplices of dimensions 1, 2 and 3.





**3D surface example** The following example use the *.geo* file *demisphere5.geo* which is in the directory *geodir* of the toolbox. This file contains description of a 3D surface mesh with simplices of dimensions 1 and 2.





## 5 PLOT function

The method `FC_SIPLT.PLOT` displays scalar datas on the mesh or parts of the mesh defined by an `SIMESH` object.

### Syntaxe

```

fc_siplt.plot(Th,u)
fc_siplt.plot(Th,u,Name,Value,...)

```

### Description

`fc_siplt.plot(Th,u)` displays data `u` on all the `Th.d`-dimensional simplices elements. The data `u` is an 1D-array of size `Th.nq` or `Th.nqGlobal` or `Th.nqParent`.

`fc_siplt.plot(Th,u,Name,Value, ...)` specifies function options using one or more `Name,Value` pair arguments. Options of first level are

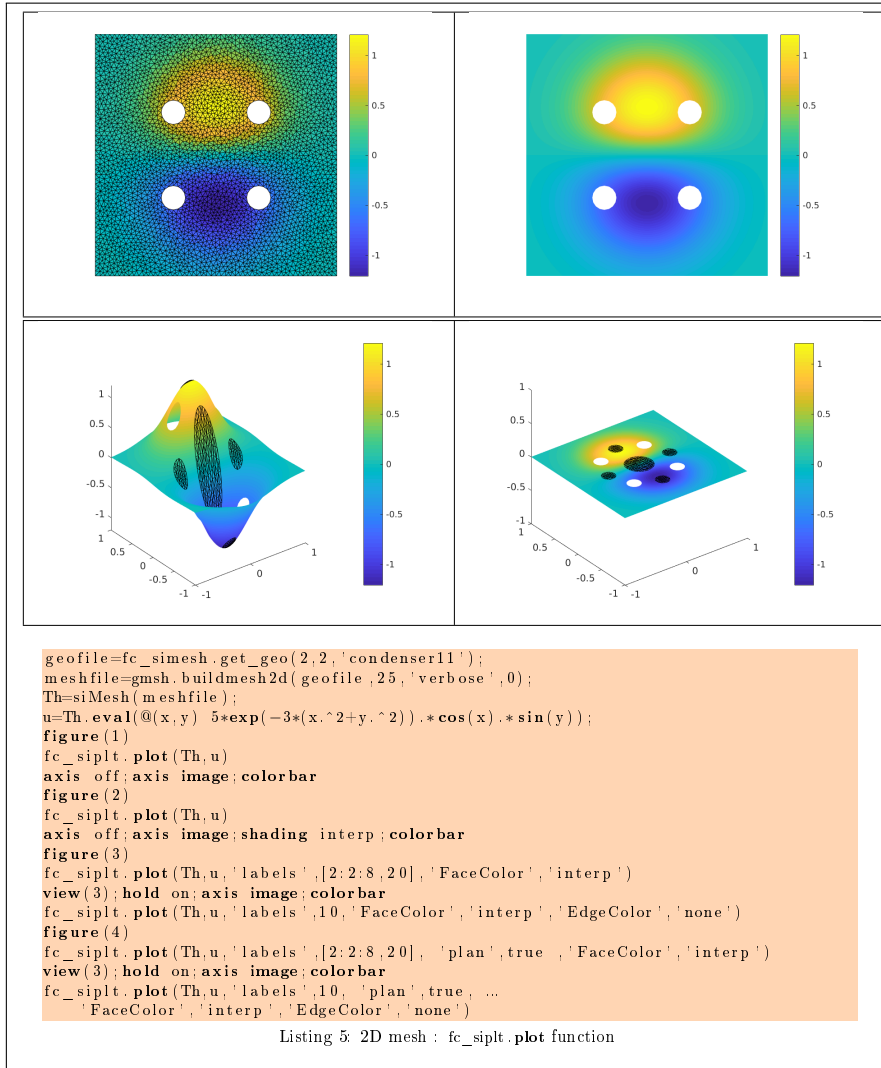
- `'d'` : to specify the dimension of the simplices elements (default : `Th.d`)
- `'labels'` : to select the labels of the elements to display data,
- `'plan'` : if true, (default : false)

The options of second level depend on the type of elementaries mesh elements on which we want to represent datas.

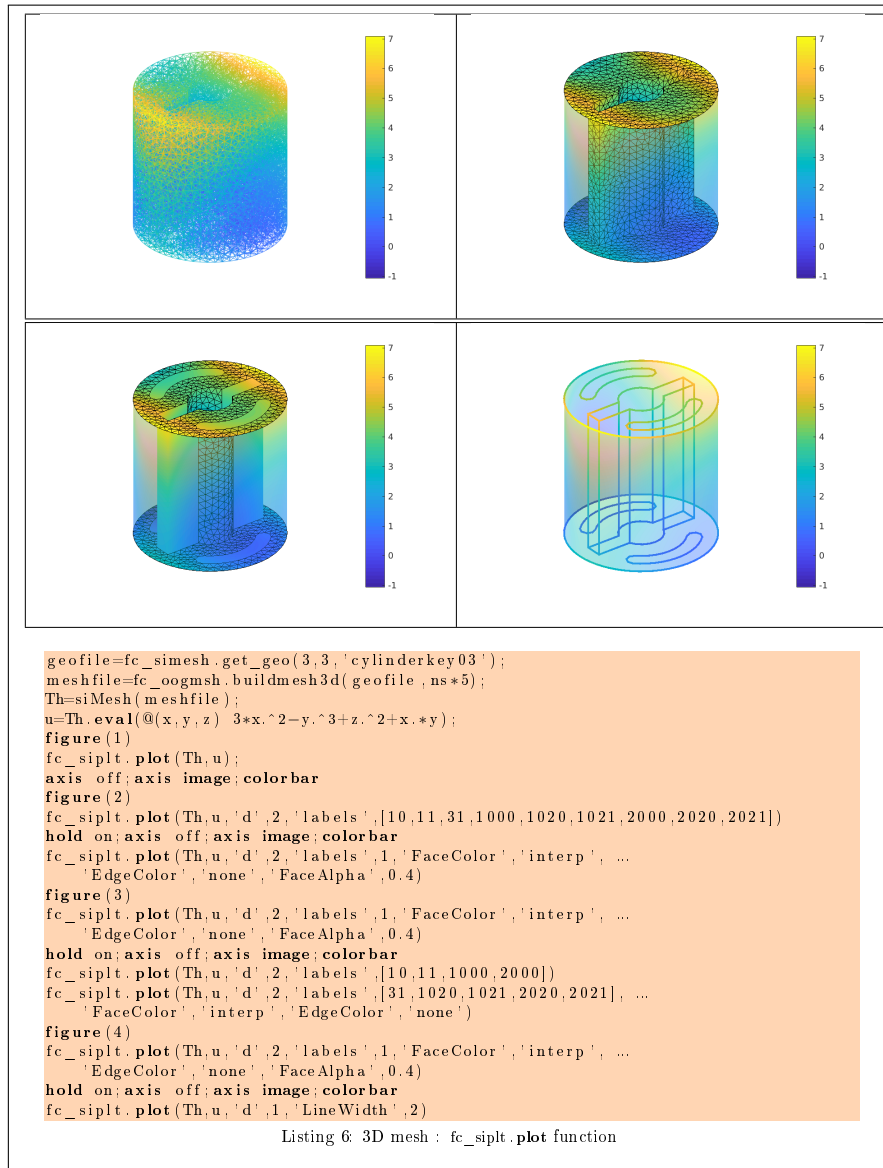
One can use any option of the following functions according to the type of  $d$ -simplex.

- In dimension 3, **patch** function is used for  $d \in \llbracket 1, 3 \rrbracket$ .
- In dimension 2,
  - for  $d == 2$ , if `'plan'` is true, **patch** function is used, otherwise `trisurf` function,
  - for  $d == 1$ , **patch** function is used.
- In dimension 1 and  $d == 1$ , **plot** function is used

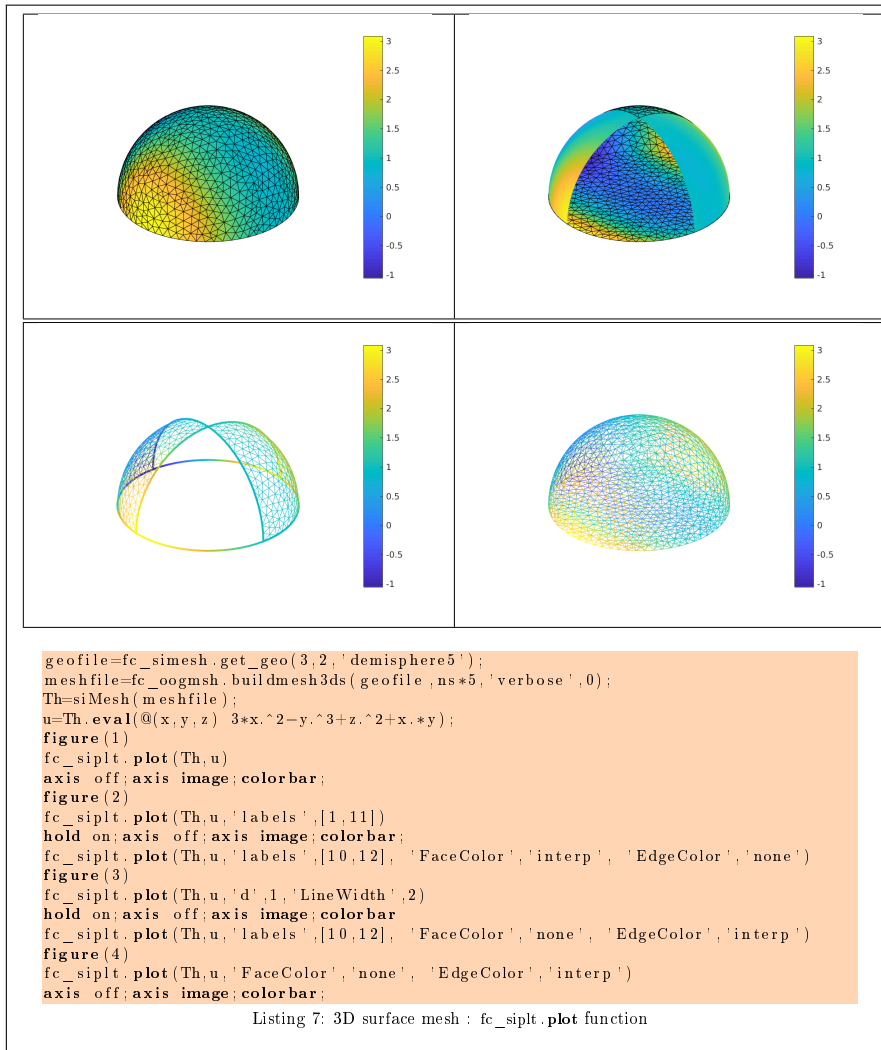
**2D example** The following example use the `.geo` file `condenser11.geo` which is in the directory `geodir` of the toolbox.



**3D example** The following example use the `.geo` file `cylinderkey.geo` which is in the directory `geodir` of the toolbox. This file contains description of a 3D mesh with simplices of dimensions 1, 2 and 3.



**3D surface example** The following example use the *.geo* file *demisphere5.geo* which is in the directory *geodir* of the toolbox. This file contains description of a 3D surface mesh with simplices of dimensions 1 and 2.



## 6 PLOTISO function

The function `FC_SIPLT.PLOTISO` displays isolines from datas on the mesh or parts of the mesh defined by an `siMESH` object. This function only works with 2-simplices in space dimension 2 or 3.

### Syntaxe

```

fc_siplt.plotiso(Th,u)
fc_siplt.plotiso(Th,u,Name,Value,...)

```

### Description

`fc_siplt.plotiso(Th,u)` displays data `u` on all the 2-dimensional simplices elements. The data `u` is an 1D-array of size `Th.nq` or `Th.nqGlobal` or `Th.nqParent`.

`fc_siplt.plotiso(Th,u,key,value, ...)` specifies function options using one or more key,value pair arguments. Options of first level are

- **'niso'** : to specify the number of isolines (default : 10)
- **'isorange'** : to specify the list of isovalues (default : empty)
- **'isocolorbar'** : if true, colorbar with isovalues is drawn (default : false)
- **'format'** : to specify the format of the isovalues on the colorbar (default : '%g')
- **'labels'** : to select the labels of the elements to display data,
- **'plan'** : if true, (default : false)
- **'color'** : to specify one color for all isolines (default : empty)
- **'mouse'** : if true, display information on clicked isoline (default : false)

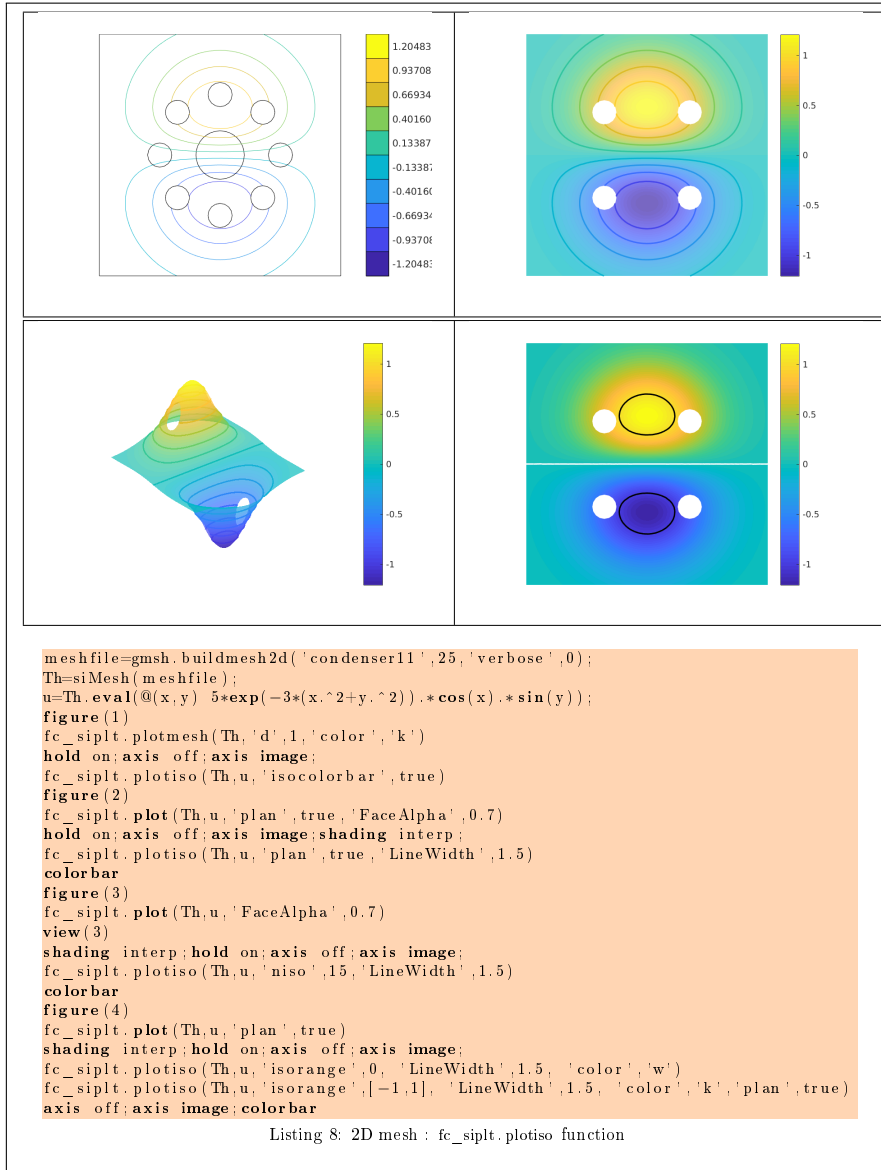
The options of second level are all options of

- **plot3** function in dimension 3 or in dimension 2 with **'plan'** set to false
- **plot** function in 2 with **'plan'** set to true

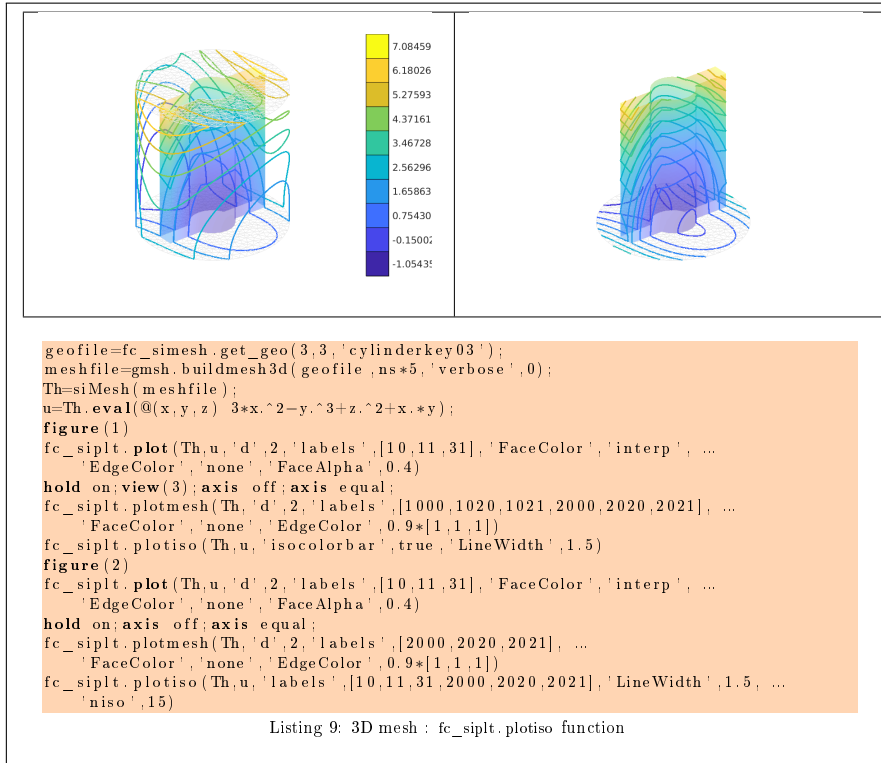
This function accepts until 4 output arguments :

- bullet* 1st output is the colors of the isolines
- bullet* 2nd output is the isovalues of the isolines
- bullet* 3th output is the handle of the colobar iso.
- bullet* 4th output is all the handles of the isolines as an 2D-array of dimension N-by-niso, where N is the number of 2-simplex elementary meshes where isolines are drawn.

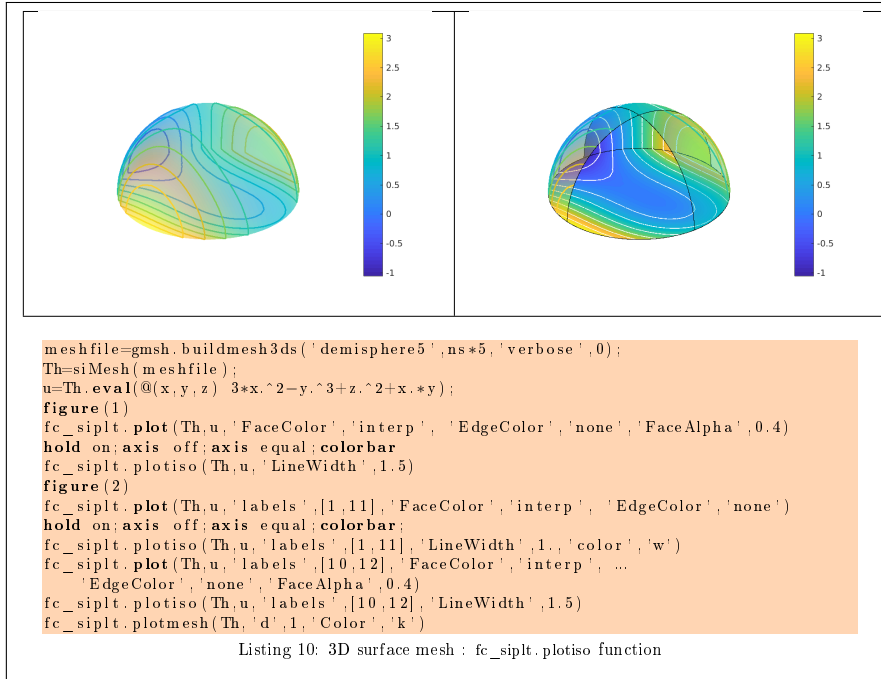
**2D example** The following example use the *.geo* file `condenser11.geo` which is in the directory `geodir` of the toolbox.



**3D example** The following example use the *.geo* file *cylinderkey.geo* which is in the directory *geodir* of the toolbox. This file contains description of a 3D mesh with simplices of dimensions 1, 2 and 3.



**3D surface example** The following example use the *.geo* file *demisphere5.geo* which is in the directory *geodir* of the toolbox. This file contains description of a 3D surface mesh with simplices of dimensions 1 and 2.





## 7 SLICEMESH function

The function `FC_SIPLT.SLICEMESH` displays intersection of a plane and a 3D mesh or parts of a 3D mesh defined by an `siMESH` object.

### Syntaxe

```
fc_siplt.slicemesh(Th,P)
fc_siplt.slicemesh(Th,P,Name,Value,...)
```

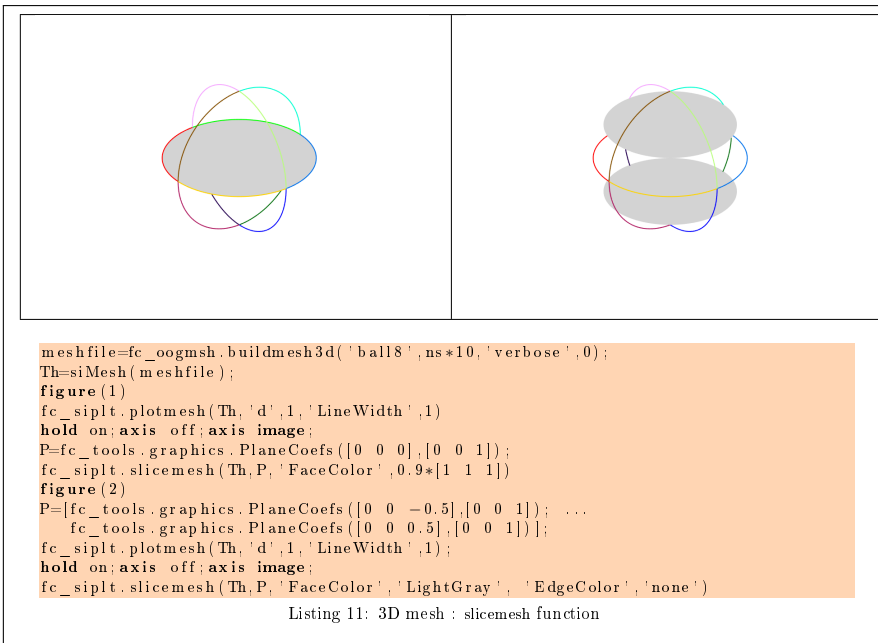
### Description

`fc_siplt.slicemesh(Th,P)` displays intersection of the plane defined by  $P(1)x + P(2)y + P(3)z + P(4) = 0$  and all the 3-dimensional simplices elements. To compute  $P$  one can use the function `PlaneCoefs` of the `FC-SIPLT` toolbox. With this function, the array  $P$ , is obtained with  $P = \text{PlaneCoefs}(Q,V)$  where  $Q$  is a point in the plane and  $V$  is a vector orthogonal to it.

`fc_siplt.plot(Th,u,Name,Value,...)` specifies function options using one or more `Name,Value` pair arguments. Options of first level are

- `'color'` : to specify the slice color (default : light grey, `rgb=[0.9,0.9,0.9]`)
- `'labels'` : to select the labels of the elements to intersect,

**3D example** The following example use the `.geo` file `ball18.geo` which is in the directory `geodir` of the toolbox. This file contains description of a 3D mesh with simplices of dimensions 1, 2 and 3.



## 8 SLICE function

The method `fc_siplt.slice` displays datas on the intersection of a plane and a 3D mesh or parts of a 3D mesh defined by an `siMESH` object.

### Syntaxe

```
fc_siplt.slice(Th,u,P)
fc_siplt.slice(Th,u,P,Name,Value, ...)
```

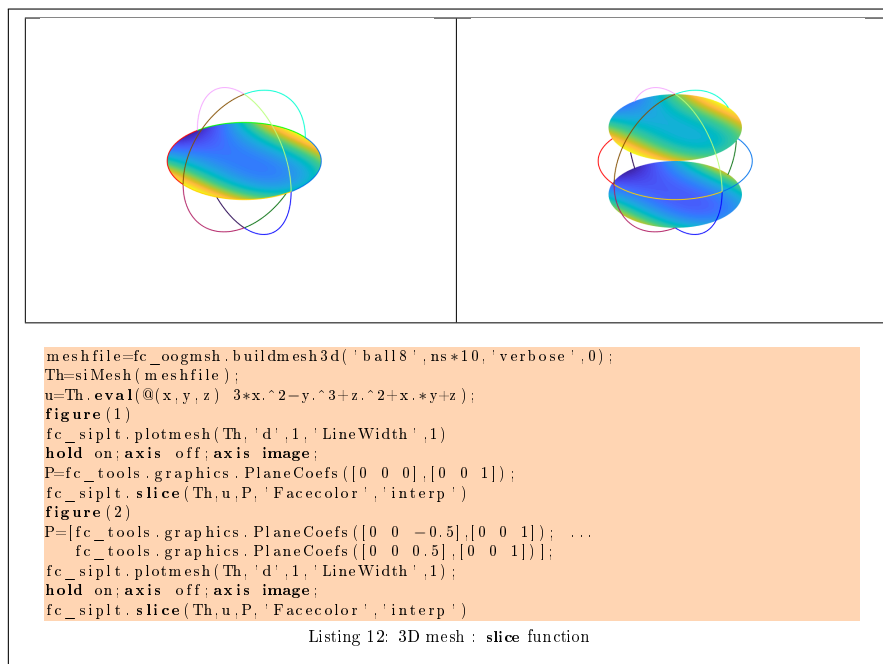
### Description

`fc_siplt.slice(Th,u,P)` displays `u` data on the intersection of the plane defined by  $P(1)x + P(2)y + P(3)z + P(4) = 0$  and all the 3-dimensional simplices elements. The data `u` is an 1D-array of size `Th.nq` or `Th.nqGlobal` or `Th.nqParent`. To compute  $P$  one can use the function `PLANECOEFS` of the `FC-TOOLS` toolbox. With this function, the array `P`, is obtained with `P=PlaneCoeFs(Q,V)` where `Q` is a point in the plane and `V` is a vector orthogonal to it.

`Th.slide(u,P,Name,Value, ...)` specifies function options using one or more `Name,Value` pair arguments. Options of first level are

- `'labels'` : to select the labels of the elements to intersect,

**3D example** The following example use the `.geo` file `ball18.geo` which is in the directory `geodir` of the toolbox. This file contains description of a 3D mesh with simplices of dimensions 1, 2 and 3.



The method `FC_SIPLT.SLICEISO` displays isolines of data on the intersection of a plane and a 3D mesh or parts of a 3D mesh defined by an `siMESH` object.

### Syntaxe

```
fc_siplt.sliceiso(Th,u,P)
fc_siplt.sliceiso(Th,u,P,Name,Value, ...)
```

### Description

`fc_siplt.sliceiso(Th,u,P)` displays `u` data as isolines on the intersection of the plane defined by  $P(1)x + P(2)y + P(3)z + P(4) = 0$  and all the 3-dimensional simplices elements. The data `u` is an 1D-array of size `Th.nq` or `Th.nqGlobal` or `Th.nqParent`. To compute  $P$  one can use the function `PlaneCoefs` of the `FC-TOOLS` toolbox. With this function, the array `P`, is obtained with `P=fc_tools.graphics.PlaneCoefs(Q,V)` where `Q` is a point in the plane and `V` is a vector orthogonal to the plane.

`fc_siplt.sliceiso(Th,u,P,key,value, ...)` allows additional key/value pairs to be used when displaying `u`. The key strings could be

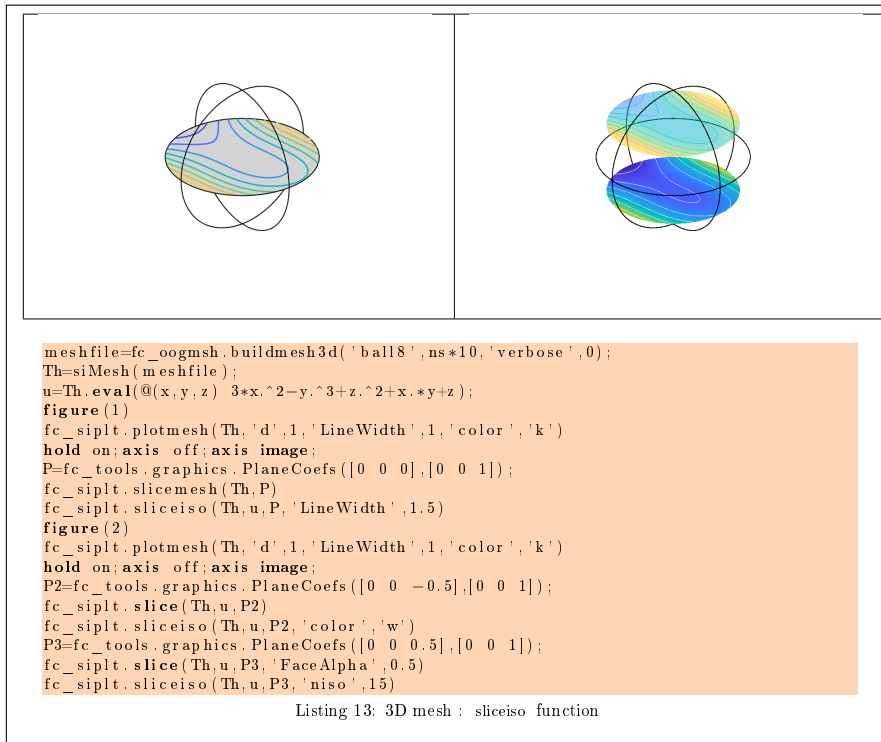
- `'labels'` : to select the labels of the elements to intersect,
- `'niso'` : to specify the number of isolines (default : 10)
- `'isorange'` : to specify the list of isovalues (default : empty)
- `'color'` : to specify one color for all isolines (default : empty)
- `'isocolorbar'` : if true display a colorbar. Default is false.
- `'format'` : to specify the format of the isovalues print in the colorbar. Default is `'%g'`.

For key strings, one could also used any options of the `plot3` function.

This function accepts until 4 output arguments :

- 1st output is the colors of the isolines
- 2nd output is the isovalues of the isolines
- 3th output is the handle of the colobar iso.
- 4th output is all the handles of the isolines as an 2D-array of dimension `N-by-niso`, where `N` is the number of elementary meshes where isolines are drawn.

**3D example** The following example use the `.geo` file `ball18.geo` which is in the directory `geodir` of the toolbox. This file contains description of a 3D mesh with simplices of dimensions 1, 2 and 3.



## 10 **PLOTQUIVER** function

The method **FC\_SIPLT.PLOTQUIVER** displays vector field datas on the mesh or parts of the mesh defined by an **SIMESH** object.

### Syntaxe

```

fc_siplt.plotquiver(Th,V)
fc_siplt.plotquiver(Th,V,Key,Value,...)

```

### Description

`fc_siplt.plotquiver(Th,V)` displays vector field  $U$  on all the  $d$ -dimensional simplices elements in dimension  $d = 2$  or  $d = 3$ . The data  $V$  is an 2D-array of size  $Th.nq$ -by- $d$  or 2-by- $Th.nq$ .

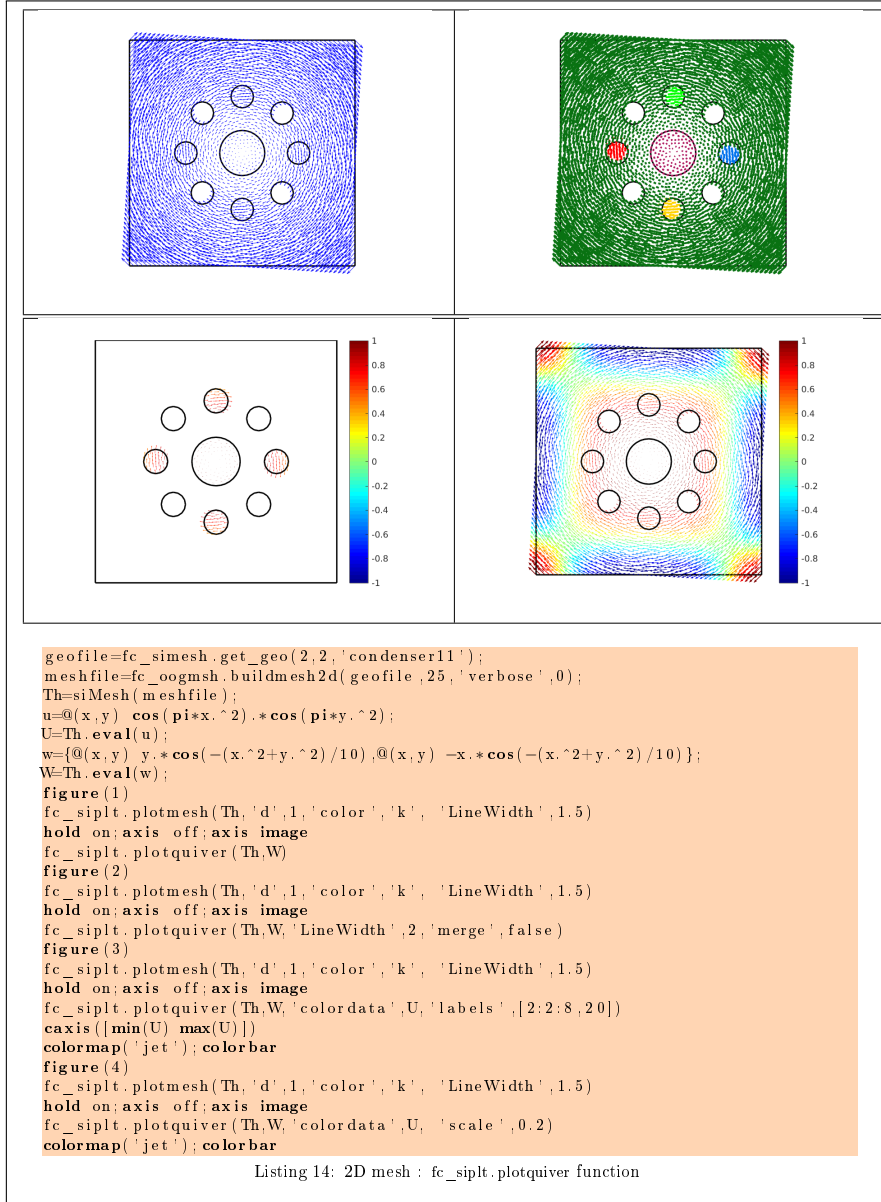
`fc_siplt.plotquiver(Th,V,Key,Value,...)` specifies function options using one or more **Key,Value** pair arguments. Options of first level are

- **'labels'** : to select the labels of the elements to display data,
- **'freq'** : quiver frequencie, (default : 1)
- **'scale'** : quiver scale, (default : ...)
- **'colordata'** : set colors on each quiver (default : empty ).

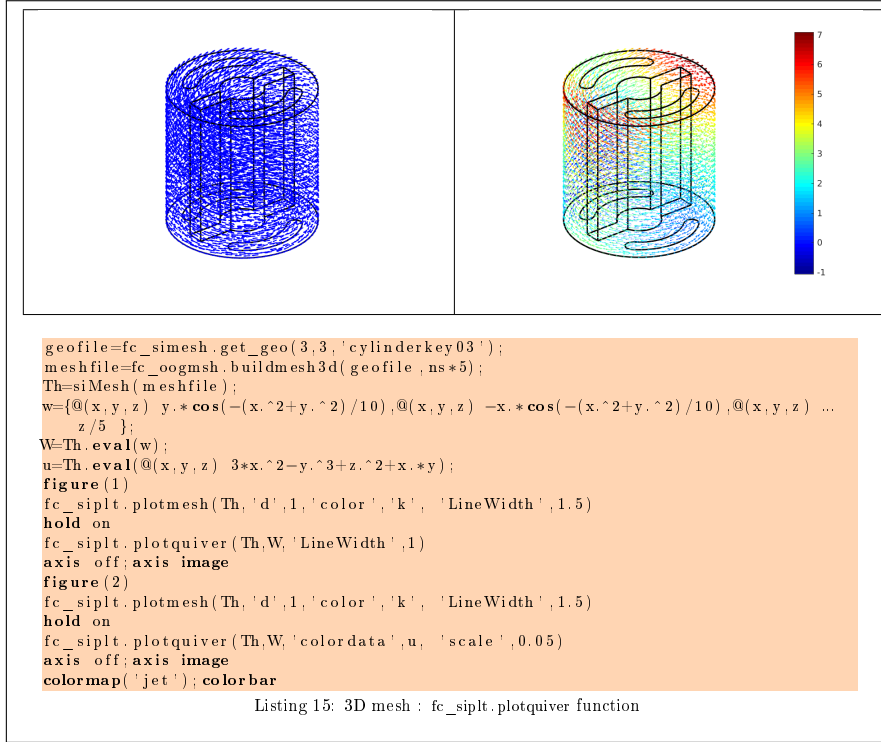
The options of second level depend on space dimension and 'colordata' option. One can use any option of the following functions

- **quiver** function in dimension 2 with an empty 'colordata'
- **quiver3** function in dimension 3 with an empty 'colordata'
- **vfield3** function in dimension 2 or 3 with 'colordata' set to an 1D-array of length Th.nq.

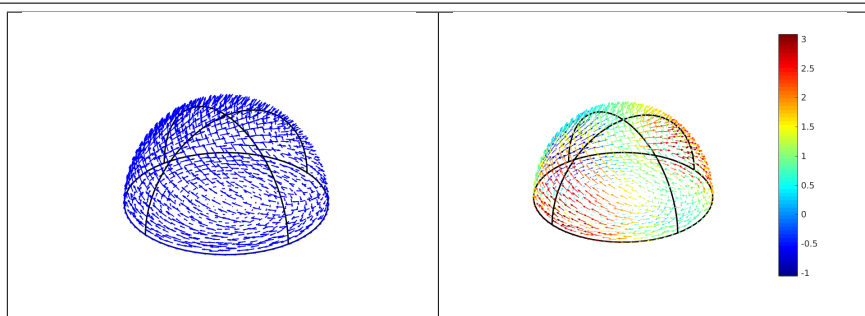
**2D example** The following example use the .geo file `condenser11.geo`.



**3D example** The following example use the *.geo* file `cylinderkey03.geo`. This file contains description of a 3D mesh with simplices of dimensions 1, 2 and 3.



**3D surface example** The following example use the *.geo* file `demisphere5.geo` which is in the directory `geodir` of the toolbox. This file contains description of a 3D surface mesh with simplices of dimensions 1 and 2.



```

geofile=fc_simesh.get_geo(3,2,'demisphere5');
meshfile=gmsb.buildmesh3ds(geofile,ns*5,'verbose',0);
Th=siMesh(meshfile);
w={@(x,y,z) y.*cos(-(x.^2+y.^2)/10),@(x,y,z) -x.*cos(-(x.^2+y.^2)/10),@(x,y,z) z ...
};
W=Th.eval(w);
u=Th.eval(@(x,y,z) 3*x.^2-y.^3+z.^2+x.*y);
figure(1)
fc_siplt.plotmesh(Th,'d',1,'color','k','LineWidth',1.5)
hold on;axis off;axis image
fc_siplt.plotquiver(Th,W,'LineWidth',1)
figure(2)
fc_siplt.plotmesh(Th,'d',1,'color','k','LineWidth',1.5)
hold on;axis off;axis image
fc_siplt.plotquiver(Th,W,'colordata',u,'scale',0.1)
colormap('jet');colorbar

```

Listing 16: 3D surface mesh : `fc_siplt.plotquiver` function