



# FC-SIMESH Matlab toolbox, User's Guide \*

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## Abstract

This object-oriented Matlab toolbox allows to use simplices meshes generated from `gmsh` (in dimension 2 or 3) or an hypercube triangulation (in any dimension). A particular care was taken to the graphics representations of meshes and datas on meshes.

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# 1 Mesh Objects

In geometry, a simplex is a generalization of the notion of a triangle or tetrahedron to arbitrary dimensions. Specifically, a  $k$ -simplex in  $\mathbb{R}^{\dim}$ ,  $k \leq \dim$ , is a polytope which is the convex hull of its  $k + 1$  vertices of  $\mathbb{R}^{\dim}$ . More formally, suppose the  $k + 1$  vertices  $q^0, \dots, q^k \in \mathbb{R}^{\dim}$  such that  $q^1 - q^0, \dots, q^k - q^0$  are linearly independent. Then, the  $k$ -simplex  $K$  determined by them is the set of points

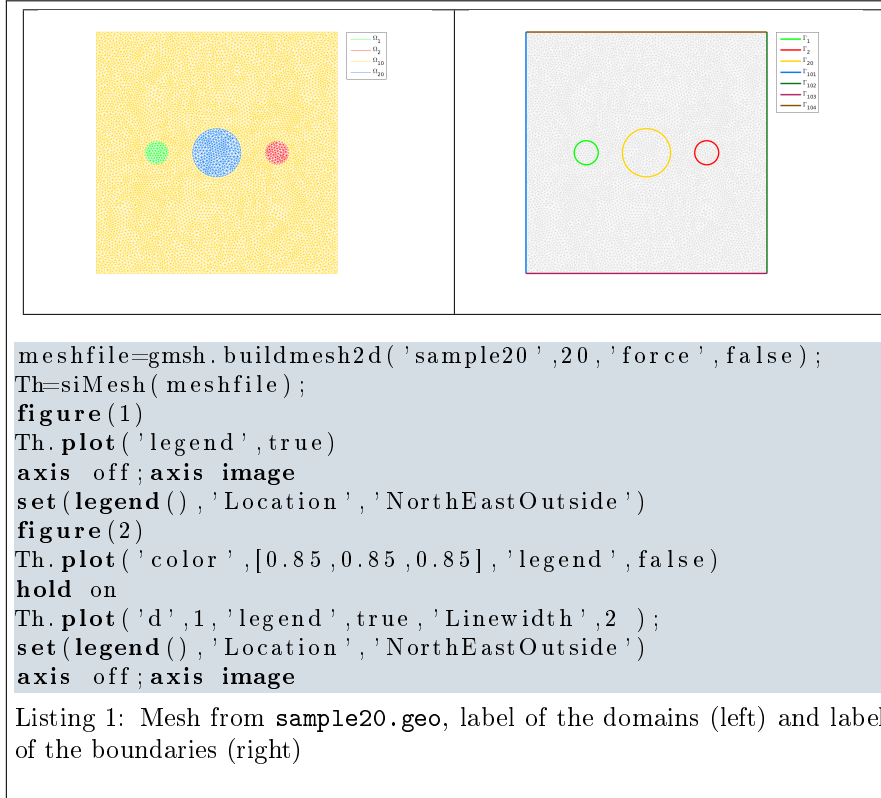
$$K = \left\{ \sum_{i=0}^k \lambda_i q^i \mid \lambda_i \geq 0, i \in \llbracket 0, k \rrbracket, \text{ with } \sum_{i=0}^k \lambda_i = 1 \right\}.$$

We denote by  **$k$ -simplicial elementary mesh** in  $\mathbb{R}^{\dim}$ ,  $k \leq \dim$ , a mesh with **unique label** only composed with  $k$ -simplices.

A  **$d$ -simplicial mesh** in  $\mathbb{R}^{\dim}$ ,  $d \leq \dim$ , is an union of  $k$ -simplicial elementary meshes with  $k \in \llbracket 0, d \rrbracket$ .

## 1.1 Mesh samples

### 1.1.1 2-simplicial mesh in $\mathbb{R}^2$



For example, from figures of Listing 13 the complete domain is

$$\Omega = \Omega_1 \cup \Omega_2 \cup \Omega_{10} \cup \Omega_{20}$$

and we note

$$\Gamma = \Gamma_1 \cup \Gamma_2 \cup \Gamma_{20} \cup \Gamma_{101} \cup \Gamma_{102} \cup \Gamma_{103} \cup \Gamma_{104}.$$

So this mesh is 2-simplicial mesh in  $\mathbb{R}^2$  and is composed of :

- four 2-simplicial elementary meshes :  $\Omega_i, \forall i \in \{1, 2, 10, 20\}$
- seven 1-simplicial elementary meshes :  $\Gamma_i \forall i \in \{1, 2, 20, 101, 102, 103, 104\}$

### 1.1.2 Sample of a 3-simplicial mesh in $\mathbb{R}^3$

```

meshfile=gmsht.buildmesh3d('quart_sphere2',5);
Th=siMesh(meshfile);
figure(1);
Th.plot('FaceAlpha',0.5,'legend',true);
hold on
Th.plot('d',1,'color',[0,0,0],'LineWidth',2);

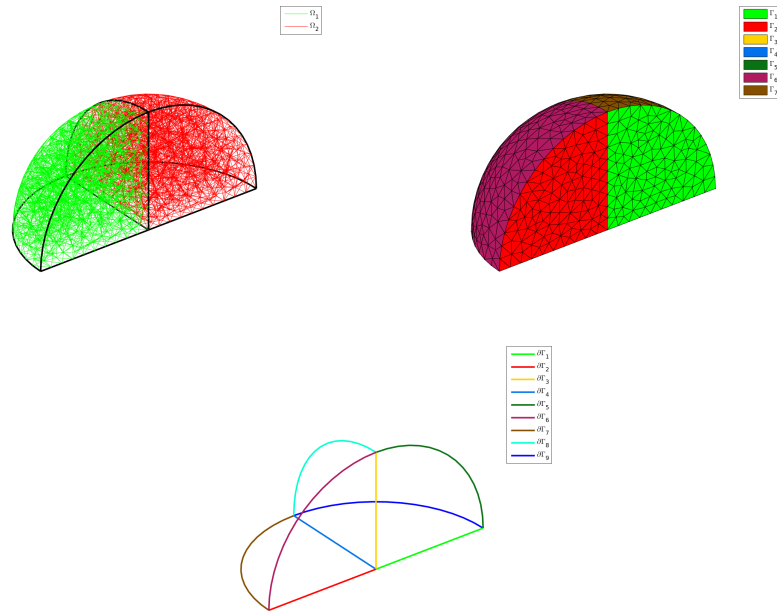
```

```

axis off; axis image;
figure(2);
Th.plot('d',2,'legend',true);
axis off; axis image
figure(3);
Th.plot('d',1,'LineWidth',2,'legend',true);
axis off; axis image

```

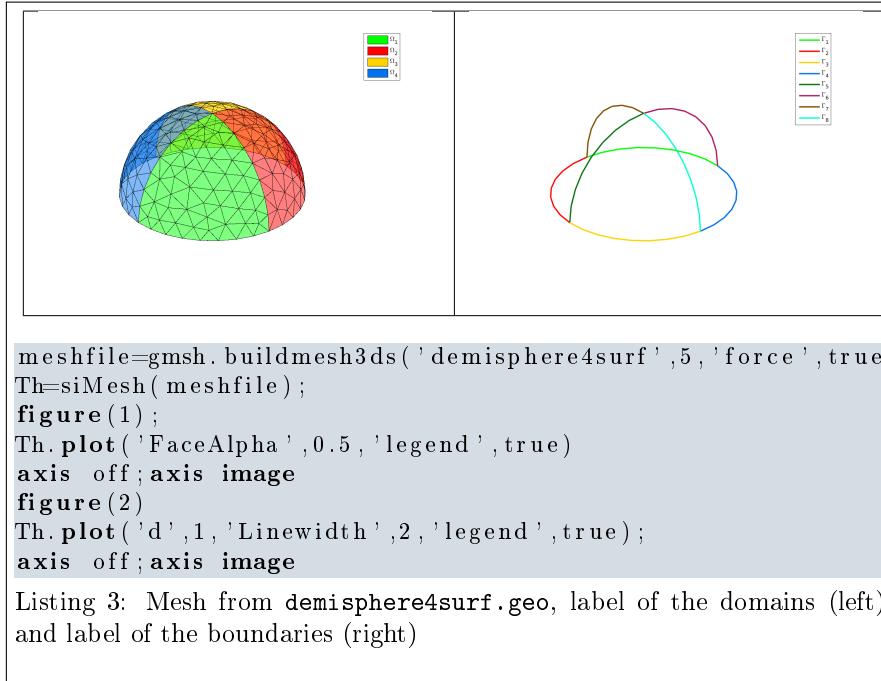
Listing 2: Mesh from quart\_sphere2.geo



The mesh obtained from Listing 14 is a 3-simplicial mesh in  $\mathbb{R}^3$  and is composed of :

- two 3-simplicial elementary meshes :  $\Omega_i, \forall i \in \{1, 2\}$
- seven 2-simplicial elementary meshes :  $\Gamma_i \forall i \in \llbracket 1, 7 \rrbracket$
- nine 1-simplicial elementary meshes :  $\partial\Gamma_i \forall i \in \llbracket 1, 9 \rrbracket$

### 1.1.3 Sample of a 2-simplicial mesh in $\mathbb{R}^3$



The mesh obtained from Listing 9 is a 2-simplicial mesh in  $\mathbb{R}^3$  and is composed of :

- four 2-simplicial elementary meshes :  $\Omega_i, \forall i \in \llbracket 1, 4 \rrbracket$
- eight 1-simplicial elementary meshes :  $\Gamma_i \forall i \in \llbracket 1, 8 \rrbracket$

## 1.2 `siMESH` object

An elementary  $d$ -simplicial mesh in dimension  $\text{dim}$  is represented by the class `siMESH`. We give properties of this class :



### Properties of **siMESH**ELT object for d-simplicial elementary meshes in $\mathbb{R}^{\text{dim}}$

dim	: integer space dimension
d	: integer ( $0 \leq d \leq \text{dim}$ )
$n_q$	: integer number of vertices
$n_{me}$	: integer number of elements (d-simplices )
q	: dim-by- $n_q$ array of reals array of vertex coordinates
me	: (d + 1)-by- $n_{me}$ array of integers connectivity array for <b>mesh elements</b>
vols	: 1-by- $n_{me}$ array of reals array of mesh element volumes
h	: double mesh step size (=maximum edge length in the mesh)
toGlobal	: 1-by- $n_q$ array of integers convert from local to global mesh vertices numbering
toParent	: 1-by- $n_q$ array of integers convert from local to parent mesh vertices numbering (same as global if not part of a partitioned mesh)

More precisely

- $q(\nu, j)$  is the  $\nu$ -th coordinate of the  $j$ -th vertex,  $\nu \in \{1, \dots, \text{dim}\}$ ,  $j \in \{1, \dots, n_q\}$ . The  $j$ -th vertex will be also denoted by  $q^j = q(:, j)$ .
- $me(\beta, k)$  is the storage index of the  $\beta$ -th vertex of the  $k$ -th element (d-simplex ), in the array  $q$ , for  $\beta \in \{1, \dots, d + 1\}$  and  $k \in \{1, \dots, n_{me}\}$ . So  $q(:, me(\beta, k))$  represents the coordinates of the  $\beta$ -th vertex of the  $k$ -th mesh element.
- $vols(k)$  is the volume of the  $k$ -th d-simplex .

### 1.3 **siMESH** object

A d-simplicial mesh in dimension  $\text{dim}$ , represented as an **siMESH** object, is an union of **siMESH**ELT objects which are elementary  $l$ -simplicial meshes ( $l \leq d$ ) in space dimension  $\text{dim}$ .

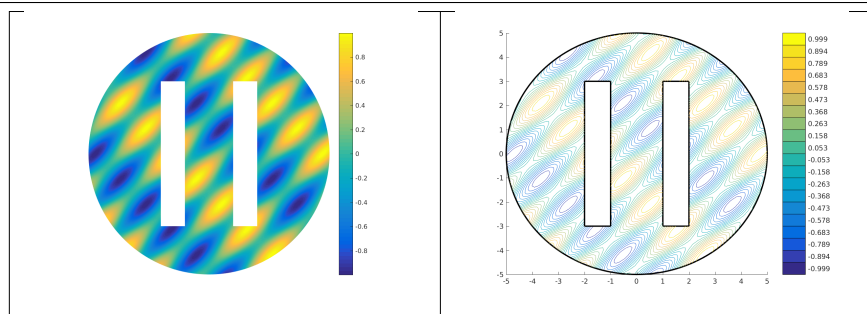


### Mesh structure associated to $\mathcal{T}_h$

<b>dim</b>	:	integer space dimension
<b>d</b>	:	integer d-dimensional simplicial mesh
<b>sTh</b>	:	array of <b>siMESH</b> <b>ELT</b> objects
<b>nsTh</b>	:	number of <b>siMESH</b> <b>ELT</b> objects
<b>sThsimp</b>	:	array of <b>nsTh</b> integers <i>i</i> -th <b>siMESH</b> <b>ELT</b> object in <b>sTh</b> is a <b>sThsimp</b> ( <i>i</i> )- simplicial elementary mesh
<b>sThlab</b>	:	array of <b>nsTh</b> integers in <b>sTh</b> label of <i>i</i> -th <b>siMESH</b> <b>ELT</b> object in <b>sTh</b> is number <b>sThlab</b> ( <i>i</i> )
<b>n<sub>q</sub></b>	:	integer number of vertices in $\mathcal{T}_h$
<b>toGlobal</b>	:	1-by- <b>n<sub>q</sub></b> array of integers convert from local to global mesh vertices numbering
<b>toParent</b>	:	1-by- <b>n<sub>q</sub></b> array of integers convert from local to parent mesh vertices numbering (same as global if not part of a partitioned mesh)

## 2 Data representation on meshes

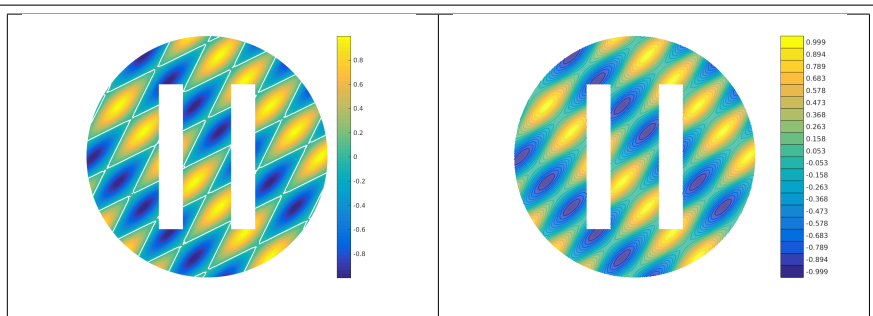
### 2.1 Data 2D mesh



```
meshfile=gmesh.buildmesh2d('condenser',10);
Th=siMesh(meshfile);
u=@(x,y) cos(2*x-y).*sin(x-2*y);
U=Th.eval(u);
figure(1);
Th.plotVal(U)
shading interp
axis off;axis image
colorbar
figure(2)
axis off;axis image
Th.plot('d',1,'color','k','Linewidth',2);
hold on
Th.plotIsolines(U,'niso',20,'isocolorbar',true,'format','%3f');
```

Listing 4: Data representations on a 2D mesh





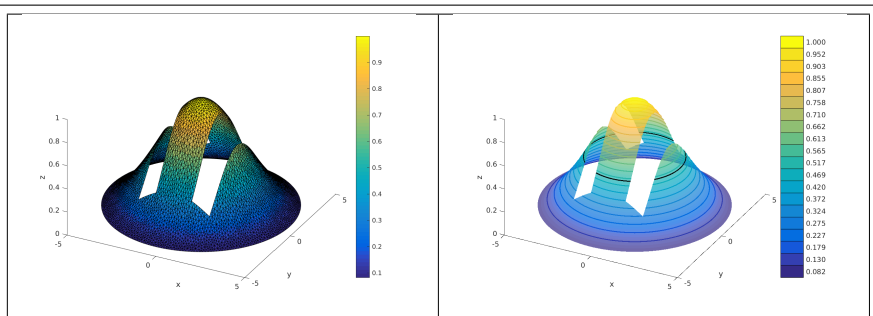
```

meshfile=gmesh.buildmesh2d('condenser',10);
Th=siMesh(meshfile);
u=@(x,y) cos(2*x-y).*sin(x-2*y);
U=Th.eval(u);
figure(1);
Th.plotVal(U)
hold on
Th.plotIsolines(U,'isorange',0,'color','w',...
'Linewidth',1.5);
axis off,axis image,shading interp,colorbar

figure(2)
Th.plotVal(U,'FaceAlpha',0.8)
hold on
[Colors,isorange]=Th.plotIsolines(U,'niso',20,...
'Linewidth',1.5);
axis off,axis image,shading interp
fc_tools.graphics.colorbarIso(Colors,isorange,'%3f')

```

Listing 5: Data representations on a 2D mesh. White lines are zero isolines (left)

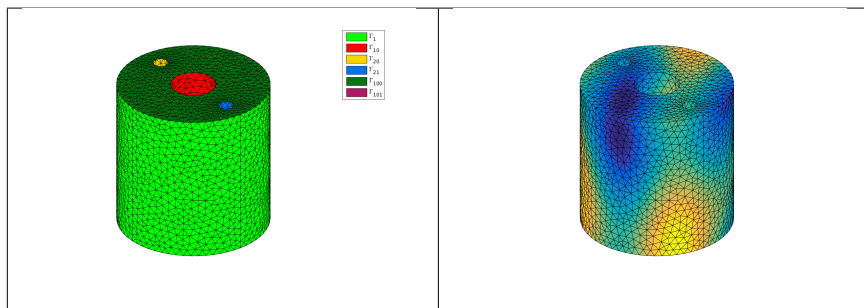


```

meshfile=gmesh.buildmesh2d('condenser',7);
Th=siMesh(meshfile);
u=@(x,y)exp(-(x.^2+y.^2)/10);
U=Th.eval(u);
figure(1)
Th.plotVal(U)
colorbar
view(27,39)
xlabel('x'),ylabel('y'),zlabel('z')
figure(2);
Th.plotVal(U,'FaceAlpha',0.7)
hold on
[Colors,isorange]=Th.plotIsolines(U,'niso',20,...
    'Linewidth',1.5);
Th.plotIsolines(U,'isorange',0.5,'color','k',...
    'Linewidth',1.5);
fc_tools.graphics.colorbarIso(Colors,isorange,'%0.3f')
shading interp
view(27,39)
xlabel('x'),ylabel('y'),zlabel('z')

```

Listing 6: Data representations on a 2D mesh. Black lines are zero isolines (right)

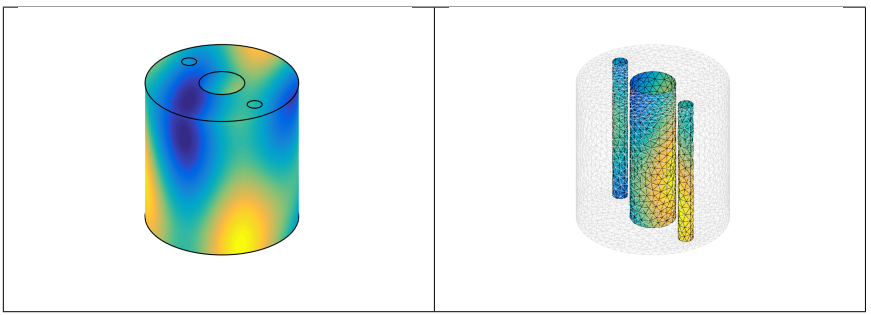


```

meshfile=gmesh.buildmesh3d('cylinder3holes',10);
Th=siMesh(meshfile);
u=@(x,y,z) cos(2*x-y-z) .* sin(x-2*y+z);
U=Th.eval(u);
figure(1);
Th.plot('d',2,'legend',true)
axis off;axis image
figure(2)
Th.plotVal(U,'d',2)
axis off;axis image

```

Listing 7: Data representations on a 3D mesh

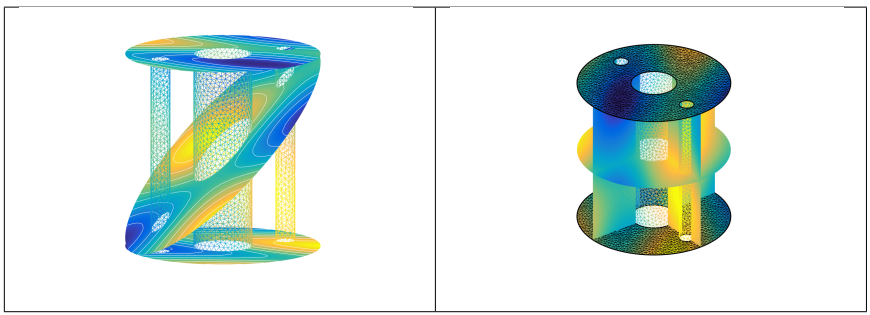


```

meshfile=gmesh.buildmesh3d('cylinder3holes',10);
Th=siMesh(meshfile);
u=@(x,y,z) cos(2*x-y-z).*sin(x-2*y+z);
U=Th.eval(u);
figure(1)
Th.plotVal(U,'d',2)
caxis([min(U),max(U)])
axis off;axis image
shading interp
hold on
Th.plot('d',1,'color','k','Linewidth',1.5)
figure(2)
Th.plot('d',2,'FaceColor','none',...
'EdgeColor',0.85*[1,1,1])
hold on
Th.plotVal(U,'d',2,'labels',[10,20,21])
caxis([min(U),max(U)])
axis off;axis image

```

Listing 8: Data representations on a 3D mesh



```

meshfile=gmsh.buildmesh3d('cylinder3holes',20);
Th=siMesh(meshfile);
u=@(x,y,z) cos(2*x-y-z).*sin(x-2*y+z);
U=Th.eval(u);
figure(1);
P=fc_tools.graphics.PlaneCoefs([0 0 1],[0 1 1]);
Th.slice(U,P,'FaceColor','interp','EdgeColor','none')
axis off,axis image,hold on
Th.plotVal(U,'d',2,'labels',[100,101], ...
'FaceColor','interp','EdgeColor','none')
caxis([min(U),max(U)])
isorange=linspace(min(U),max(U),10);
Th.plotVal(U,'d',2,'labels',[10,20,21], ...
'FaceColor','none','EdgeColor','interp')
Th.plotIsolines(U,'labels',[100,101], ...
'isorange',isorange,'color','w')
Th.isoslice(U,P,'isorange',isorange,'color','w')
view(-114,11)
figure(2)
P1=fc_tools.graphics.PlaneCoefs([0 0 1],[1 0 0]);
Th.slice(U,P1,'FaceColor','interp','EdgeColor','none')
hold on
P2=fc_tools.graphics.PlaneCoefs([0 0 1],[0 1 0]);
Th.slice(U,P2,'FaceColor','interp','EdgeColor','none')
P3=fc_tools.graphics.PlaneCoefs([0 0 1],[0 0 1]);
Th.slice(U,P3,'FaceColor','interp','EdgeColor','none')
Th.plotVal(U,'d',2,'labels',[100,101], ...
'FaceColor','interp')
Th.plotVal(U,'d',2,'labels',[10,20,21], ...
'FaceColor','none','EdgeColor','interp')
caxis([min(U),max(U)])
Th.plot('d',1,'Color','k','Linewidth',1.5)
axis off,axis image

```

Listing 9: Data representations on a 3D mesh

### 2.2.1 Mapping of the unit ball

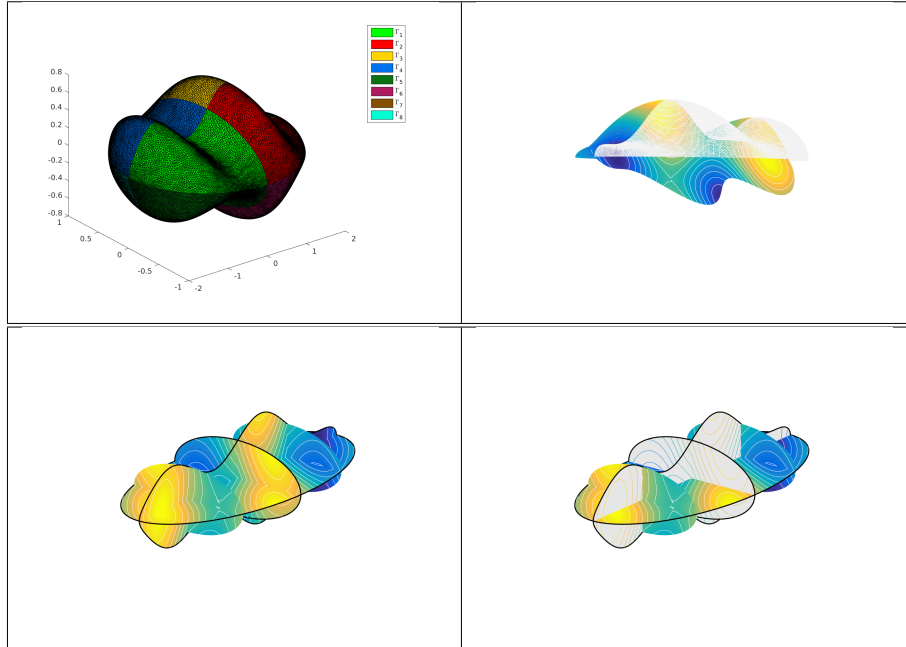
The 3D domain  $\Omega$  is constructed by mapping a discretization of the unit ball onto  $\Omega$  by

$$F(y_1, y_2, y_3) = \begin{pmatrix} 2y_1 \\ y_2 \\ \frac{1}{2}y_3(1 + \frac{1}{2}\sin(2\pi y_1)) \end{pmatrix}, \quad \forall \mathbf{y} = (y_1, y_2, y_3), \text{ such that } \|\mathbf{y}\|_2 \leq 1$$

We represent the function

$$u(x, y, z) = \cos(2x - y - z) \sin(x - 2y + z)$$

on  $\Omega$  by mapping the unit ball obtained from gmsh with `ball18.geo`.



```

trans=@(q) [2*q(1,:);q(2,:);0.5*q(3,:).*(1+0.5*sin(2*pi*q(1,:)))]];
meshfile=gmsh.buildmesh3d('ball8',40);
Th=siMesh(meshfile,'trans',trans);
u=@(x,y,z) cos(2*x-y-z).*sin(x-2*y+z);
U=Th.eval(u);
figure(1)
axis off;axis image
Th.plot('d',2,'legend',true);
figure(2)
P=fc_tools.graphics.PlaneCoefs([0 0 0],[0 1 1]);
Th.slice(U,P)
hold on
Th.plotVal(U,'d',2,'labels',[1,2], 'EdgeColor','None')
caxis([min(U),max(U)])
isorange=linspace(min(U),max(U),15);
Th.plot('d',2,'labels',[3,4], 'FaceColor','none', ...
'EdgeColor',0.95*[1,1,1])
Th.plotIsolines(U,'labels',[3,4], 'isorange',isorange, 'color','w')
Th.isoslice(U,P,'isorange',isorange, 'color','w')
axis off;axis image
view(127,-1)
figure(3)
Options={'FaceColor','interp', 'EdgeColor','none'};
P1=fc_tools.graphics.PlaneCoefs([0 0 0],[1 0 0]);
Th.slice(U,P1, Options{:})
hold on
Th.isoslice(U,P1,'isorange',isorange, 'color','w')
P2=fc_tools.graphics.PlaneCoefs([0 0 0],[0 1 0]);
Th.slice(U,P2,Options{:})
Th.isoslice(U,P2,'isorange',isorange, 'color','w')
P3=fc_tools.graphics.PlaneCoefs([0 0 0],[0 0 1]);
Th.slice(U,P3,Options{:})
Th.isoslice(U,P3,'isorange',isorange, 'color','w')
P4=fc_tools.graphics.PlaneCoefs([-1 0 0],[1 0 0]);
Th.slice(U,P4,Options{:})
Th.isoslice(U,P4,'isorange',isorange, 'color','w')
P5=fc_tools.graphics.PlaneCoefs([1 0 0],[1 0 0]);
Th.slice(U,P5,Options{:})
Th.isoslice(U,P5,'isorange',isorange, 'color','w')
Th.plot('d',1, 'color','k','Linewidth',1.5)
axis off;axis image
view(-52,20)
figure(4)
P1=fc_tools.graphics.PlaneCoefs([0 0 0],[1 0 0]);
Th.slicemesh(P1,'FaceColor',0.9*[1 1 1], 'EdgeColor','none')
hold on
Th.isoslice(U,P1,'isorange',isorange)
P2=fc_tools.graphics.PlaneCoefs([0 0 0],[0 1 0]);
Th.slicemesh(P2,'FaceColor',0.9*[1 1 1], 'EdgeColor','none')
Th.isoslice(U,P2,'isorange',isorange)
P3=fc_tools.graphics.PlaneCoefs([0 0 0],[0 0 1]);
Th.slice(U,P3,'FaceColor','interp')
Th.isoslice(U,P3,'isorange',isorange, 'color','w')
P4=fc_tools.graphics.PlaneCoefs([-1 0 0],[1 0 0]);
Th.slice(U,P4,'FaceColor','interp')
Th.isoslice(U,P4,'isorange',isorange, 'color','w')
P5=fc_tools.graphics.PlaneCoefs([1 0 0],[1 0 0]);
Th.slice(U,P5,'FaceColor','interp')
Th.isoslice(U,P5,'isorange',isorange, 'color','w')
Th.plot('d',1,'legend',false, 'color','k', 'Linewidth',1.5)
axis off;axis image;
view(-52,20)

```

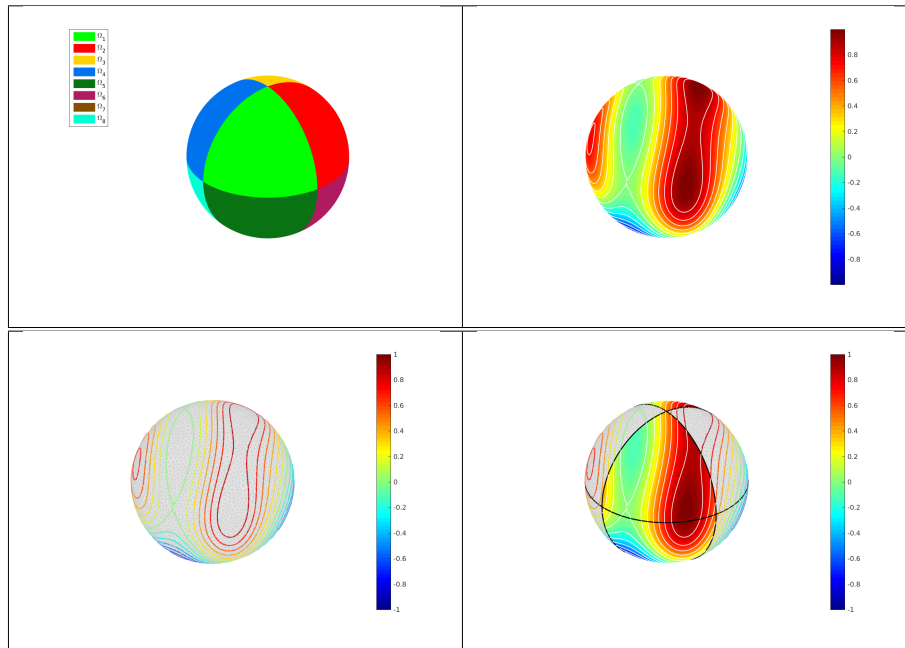
Listing 10: Data representations on a 3D mesh

## 2.3.1 Unit sphere

We represent the function

$$u(x, y, z) = \cos(2x - y - z) \sin(x - 2y + z)$$

on the unit sphere obtained from gmsh with `sphere8surf.geo`.



```

meshfile=gmsh.buildmesh3ds('sphere8surf',20);
Th=siMesh(meshfile);
u=@(x,y,z) cos(2*x-y-z).*sin(x-2*y+z);
U=Th.eval(u);
figure(1)
Th.plot('legend',true,'EdgeColor','None')
axis off;axis image
set(legend(),'Location','NorthWestOutside')
hfig=figure(2);
Th.plotVal(U,'d',2)
hold on
Th.plotIsolines(U,'niso',15,'color',[1 1 1], 'Linewidth',1)
caxis([min(U),max(U)])
axis off, axis image
shading interp,colormap(jet)
h=colorbar;
%set(hfig,'Position',[0 0 800 600])
%set(h,'Position',[0.75 0.25 0.025 0.50])
figure(3)
colormap(jet)

```



```

Th. plot('FaceColor',0.9*[1 1 1], 'EdgeColor',0.8*[1 1 1]);
hold on
Th. plotIsolines(U, 'niso',15, 'Linewidth',1.5)
axis off, axis image
h=colorbar;
%set(hfig, 'Position',[0 0 800 600])
%set(h, 'Position',[0.75 0.25 0.025 0.50])
hfig=figure(4);
colormap(jet)
Th. plotVal(U, 'd',2, 'labels',[1:2:8], 'FaceColor','interp', 'EdgeColor','None')
hold on
Th. plotIsolines(U, 'labels',[1:2:8], 'niso',15, 'color',[1 1 ...
1], 'Linewidth',1)
Th. plot('labels',[2:2:8], 'FaceColor',0.9*[1 1 1], ...
'EdgeColor',0.8*[1 1 1]);
Th. plotIsolines(U, 'labels',[2:2:8], 'niso',15, 'Linewidth',1.5)
axis off, axis image
Th. plot('d',1, 'color',[0 0 0], 'Linewidth',1.5)
h=colorbar;
%set(hfig, 'Position',[0 0 800 600])
%set(h, 'Position',[0.75 0.25 0.025 0.50])

```

Listing 11: Data representations on a 3D surface mesh

### 2.3.2 Mapping of the unit sphere

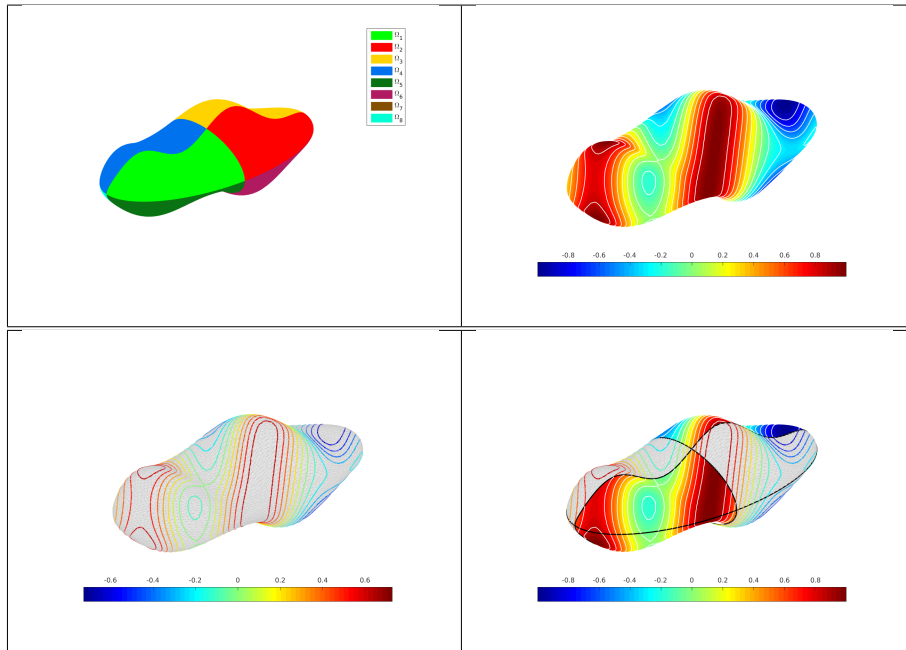
The hypersurface is constructed by mapping a discretization of the unit sphere  $S^2$  onto the surface  $\Omega$  by

$$F(y_1, y_2, y_3) = \begin{pmatrix} 2y_1 \\ y_2 \\ \frac{1}{2}y_3(1 + \frac{1}{2}\sin(2\pi y_1)) \end{pmatrix}, \quad \forall \mathbf{y} = (y_1, y_2, y_3) \in S^2$$

We represent the function

$$u(x, y, z) = \cos(2x - y - z) \sin(x - 2y + z)$$

on the surface  $\Omega$  by mapping the unit sphere obtained from `gmsh` with `sphere8surf.geo`.



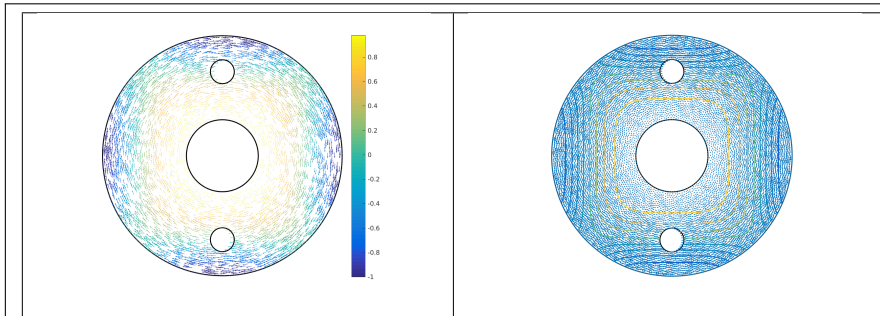
```

meshfile=gsmsh.buildmesh3ds('sphere8surf',20);
Th=siMesh(meshfile);
u=@(x,y,z) cos(2*x-y-z).*sin(x-2*y+z);
U=Th.eval(u);
figure(1)
Th.plot('legend',true,'EdgeColor','None')
axis off;axis image
set(legend(),'Location','NorthWestOutside')
hfig=figure(2);
Th.plotVal(U,'d',2)
hold on
Th.plotIsolines(U,'niso',15,'color',[1 1 1], 'Linewidth',1)
caxis([min(U),max(U)])
axis off, axis image
shading interp,colormap(jet)
h=colorbar;
%set(hfig,'Position',[0 0 800 600])
%set(h,'Position',[0.75 0.25 0.025 0.50])
figure(3)
colormap(jet)
Th.plot('FaceColor',0.9*[1 1 1], 'EdgeColor',0.8*[1 1 1]);
hold on
Th.plotIsolines(U,'niso',15, 'Linewidth',1.5)
axis off, axis image
h=colorbar;
%set(hfig,'Position',[0 0 800 600])
%set(h,'Position',[0.75 0.25 0.025 0.50])
hfig=figure(4);
colormap(jet)
Th.plotVal(U,'d',2,'labels',[1:2:8], 'FaceColor','interp', 'EdgeColor','None')
hold on
Th.plotIsolines(U,'labels',[1:2:8], 'niso',15, 'color',[1 1 1], ...
'Linewidth',1)
Th.plot('labels',[2:2:8], 'FaceColor',0.9*[1 1 1], 'EdgeColor',0.8*[1 1 ...
1]);
Th.plotIsolines(U,'labels',[2:2:8], 'niso',15, 'Linewidth',1.5)
axis off, axis image
Th.plot('d',1,'color',[0 0 0], 'Linewidth',1.5)
h=colorbar;
%set(hfig,'Position',[0 0 800 600])
%set(h,'Position',[0.75 0.25 0.025 0.50])

```

Listing 12: Data representations on a 3D surface mesh

## 2.4.1 2D mesh



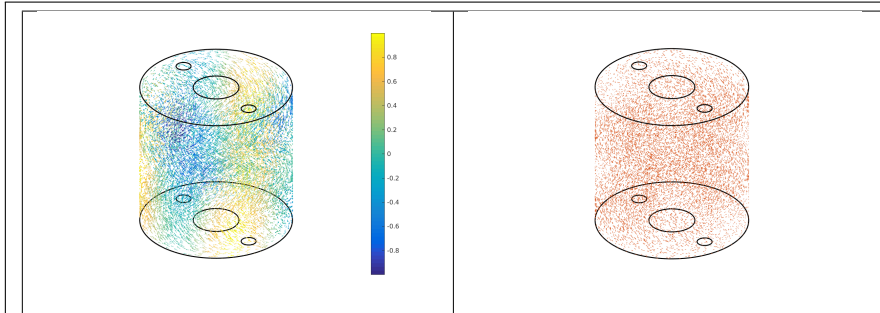
```

meshfile=gmesh.buildmesh2d('disk3holes',50);
Th=siMesh(meshfile);
u=@(x,y) cos(pi*x.^2).*cos(pi*y.^2);
U=Th.eval(u);
w={@(x,y) y.*cos(-(x.^2+y.^2)/10);@(x,y) ...
    -x.*cos(-(x.^2+y.^2)/10)};
W=[Th.eval(w{1}),Th.eval(w{2})]';
figure(1);
Th.plot('d',1,'color','k','LineWidth',1.5)
hold on
Th.plotVectorField(W,'colordata',U,'freq',2,'scale',0.05)
axis off;axis image
colorbar
figure(2)
Th.plot('d',1,'color','k','LineWidth',1.5)
hold on
Th.plotVectorField(W,'LineWidth',1)
Th.plotIsolines(U,'LineWidth',1.5)
axis off;axis image
colormap('jet')

```

Listing 13: Vector field representations on a 2D mesh

## 2.4.2 3D mesh



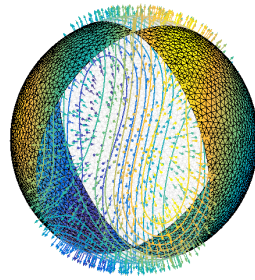
```

meshfile=gmesh.buildmesh3d('cylinder3holes',20);
Th=siMesh(meshfile);
u=@(x,y,z) cos(2*x-y-z).*sin(x-2*y+z);
U=Th.eval(u);
w={@(x,y,z) y.*cos(-(x.^2+y.^2)/10);@(x,y,z) ...
    -x.*cos(-(x.^2+y.^2)/10); @(x,y,z) sin(2*pi*z)};
W=[Th.eval(w{1}),Th.eval(w{2}),Th.eval(w{3})];
figure(1);
Th.plot('d',1,'color','k','Linewidth',1.5)
hold on
Th.plotVectorField(W,'colordata',U,'freq',3,'scale',0.05)
view(3)
axis off;axis image
colorbar
figure(2)
Th.plot('d',1,'color','k','Linewidth',1.5)
hold on
Th.plotVectorField(W,'freq',3)
view(3)
axis off;axis image

```

Listing 14: Vector field representations on a 3D mesh

### 2.4.3 3D surface mesh



```
meshfile=gmesh. buildmesh3ds( ' sphere8surf ' ,20 );
Th=siMesh( meshfile );
u=@(x,y,z) cos(2*x-y-z) .* sin(x-2*y+z);
U=Th. eval(u);
w=@(x,y,z) x;@(x,y,z) y; @(x,y,z) z};
W=[Th. eval(w{1}),Th. eval(w{2}),Th. eval(w{3})];
figure(1)
Th. plot( ' labels ' ,1:2:8, ' FaceColor ' , ' none ' , ...
' EdgeColor ' ,0.8*[1 1 1], ' EdgeAlpha ' ,0.3);
hold on
Th. plotIsolines(U, ' labels ' ,[1:2:8], ' niso ' ,15, ...
' Linewidth ' ,1);
Th. plotVectorField(W, ' colordata ' ,U, ' labels ' ,1:2:8, ...
' freq ' ,3, ' scale ' ,0.1)
Th. plotVal(U, ' d ' ,2, ' labels ' ,[2:2:8]);
axis off;axis image
```

Listing 15: Vector field representation on a 3D surface mesh

## 3 Functions of the fc-simesh toolbox

### 3.1 siMESH methods

#### 3.1.1 siMESH constructor

The constructor of the `siMESH` class can initialize the object from various kind of mesh file format : `.msh` (default gmsh format), `.mesh` ( FreeFEM++ or Medit) or ... (triangle).

## Syntaxe

```
Th=siMesh(meshfile)
Th=siMesh(meshfile,Name,Value)
```

## Description

`Th=siMesh(meshfile)` create the `siMESH` object `Th` from the mesh file `meshfile` (gmsH format by default).

`Th=siMesh(meshfile,Name,Value, ...)` specifies function options using one or more `Name,Value` pair arguments. The `Name` options can be

- `'format'` : to specify the format of the mesh file `meshfile`. Value must be `'medit'`, `'gmsH'` (default), `'freefem'` or `'triangle'`.
- `'dim'` : to specify the space dimension (default 2),
- `'d'` : to specify the dimensions of the simplices to read, (default [dim,dim-1])

**Examples** The following example use the function `gmsH.buildmesh2d` of the `fc-oogmsH` toolbox to build the mesh from the `.geo` file `condenser11.geo`. This `.geo` file is located in the directory `geodir` of the `fc-oogmsH` toolbox.

```
Matlab commands with output
meshfile=gmsH.buildmesh2d('condenser11',25,'verbose',0);
disp('***_Read_mesh_***')
Th=siMesh(meshfile)

*** Read mesh ***
Th =

siMesh with properties:
    d: 2 double
   dim: 2 double
    sTh: (1x19 cell)
   nsTh: 19 double
 toGlobal: (1x2990 double)
 toParent: (1x2990 double)
  sThsimp: (1x19 double)
  sThlab: (1x19 double)
 sThcolors: (19x3 double)
      bbox: [-2 2 -2 2] (1x4 double)
  sThgeolab: []
  sThphyslab: (1x6 double)
  sThpartlab: []
         nq: 2990 double
```

### 3.1.2 function `PLOT`

The method `PLOT` displays the mesh or parts of the mesh defined by an `siMESH` object.

## Syntaxe

```
Th.plot()
Th.plot(Name, Value, ...)
```

## Description

`Th.plot()` displays all the `Th.d`-dimensional simplices elements.

`Th.plot(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),
- `'legend'` : add a legend to graph if true (default : false)
- `'bounds'` : If true, draw the borders of each one of the selected elementaries mesh elements (only for 2-dimensional simplices). (default : false)

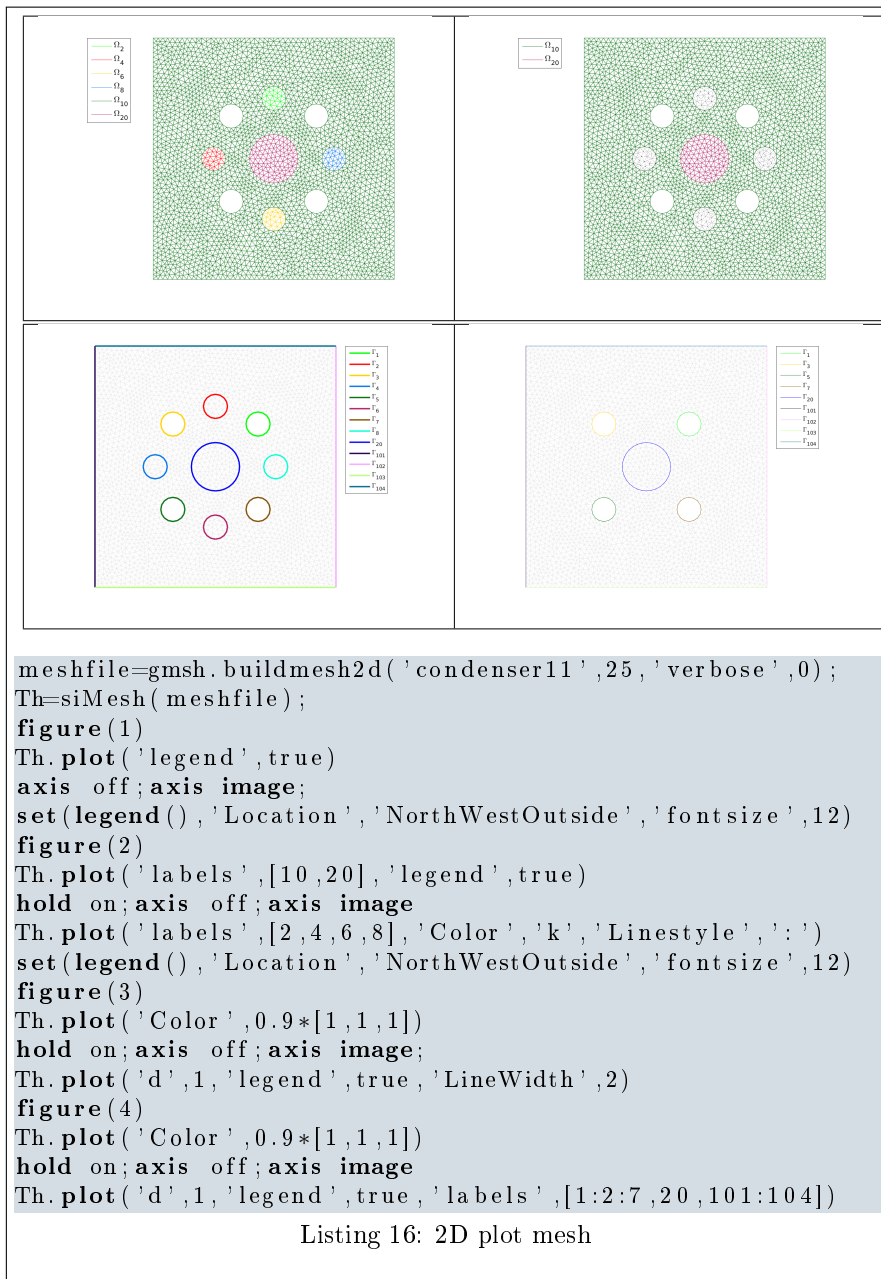
The options of second level depend on the type of elementaries mesh elements to represent.

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

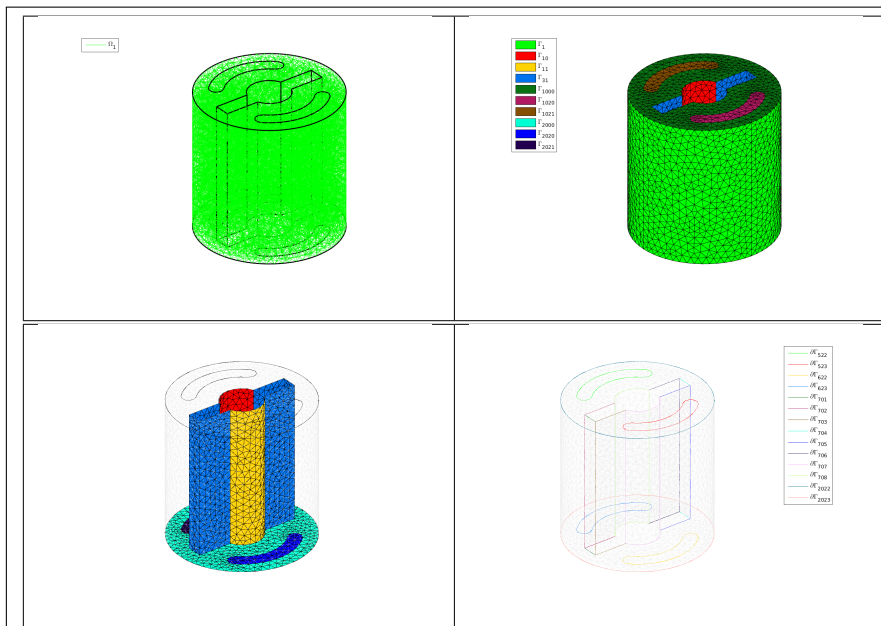
- In dimension 3,
  - if  $d == 3$ , `tetramesh` function is used,
  - if  $d == 2$ , `trimesh` function is used,
  - if  $d == 1$ , `line` function is used,
  - if  $d == 0$ , `plot3` function is used,
- In dimension 2,
  - if  $d == 2$ , `triplot` function is used,
  - if  $d == 1$ , `line` function 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.



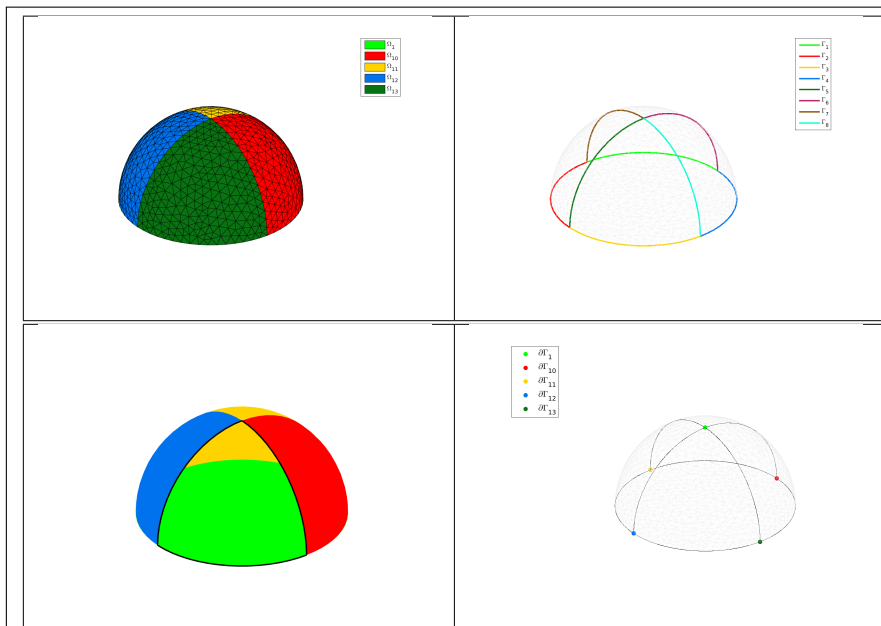
```

meshfile=gmsl.buildmesh3d('cylinderkey',10,'verbose',0);
Th=siMesh(meshfile);
figure(1)
Th.plot('legend',true)
hold on
Th.plot('d',1,'Color','k','Linewidth',1.5)
axis off;axis image
set(legend(),'Location','NorthWestOutside')
figure(2)
Th.plot('d',2,'legend',true)
view(3);hold on;axis off;axis image
set(legend(),'Location','NorthWestOutside')
figure(3)
Th.plot('d',2,'labels',[1,1000,1020,1021], ...
        'EdgeColor',0.9*[1,1,1], ...
        'EdgeAlpha',0.4,'FaceColor','none')
hold on;axis off;axis image
Th.plot('d',2,'labels',1000,'bounds',true,'color','k')
Th.plot('d',2,'labels',[10,11,31,2000,2020,2021])
figure(4)
Th.plot('d',2,'EdgeColor',0.9*[1,1,1], ...
        'EdgeAlpha',0.4,'FaceColor','none')
hold on;axis off;axis image
Th.plot('d',1,'legend',true)

```

Listing 17: 3D plot mesh

**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.



```

meshfile=gmsl.buildmesh3ds('demisphere5',10,'verbose',0);
Th=siMesh(meshfile);
figure(1)
Th.plot('legend',true)
axis off;axis equal
figure(2)
Th.plot('EdgeColor',0.9*[1,1,1], ...
        'EdgeAlpha',0.4,'FaceColor','none')
view(3);hold on;axis off;axis equal
set(legend(),'Location','NorthWestOutside','FontSize',12)
Th.plot('d',1,'legend',true,'LineWidth',2)
figure(3)
Th.plot('labels',[1,10,11,12],'EdgeColor','none')
hold on;axis off;axis equal
Th.plot('labels',13,'bounds',true,'color','k','LineWidth',2)
figure(4)
Th.plot('EdgeColor',0.9*[1,1,1], ...
        'EdgeAlpha',0.4,'FaceColor','none')
hold on;axis off;axis equal
Th.plot('d',1,'color','k')
Th.plot('d',0,'legend',true)
set(legend(),'Location','NorthWestOutside','FontSize',12)

```

Listing 18: 3D surface mesh : plot function

### 3.1.3 function `PLOTVAL`

The method `PLOTVAL` displays data on the mesh or parts of the mesh defined by an `siMESH` object.

#### Syntaxe

```
Th.plotVal(u)
Th.plotVal(u,Name,Value, ...)
```

## Description

`Th.plotVal(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`.

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

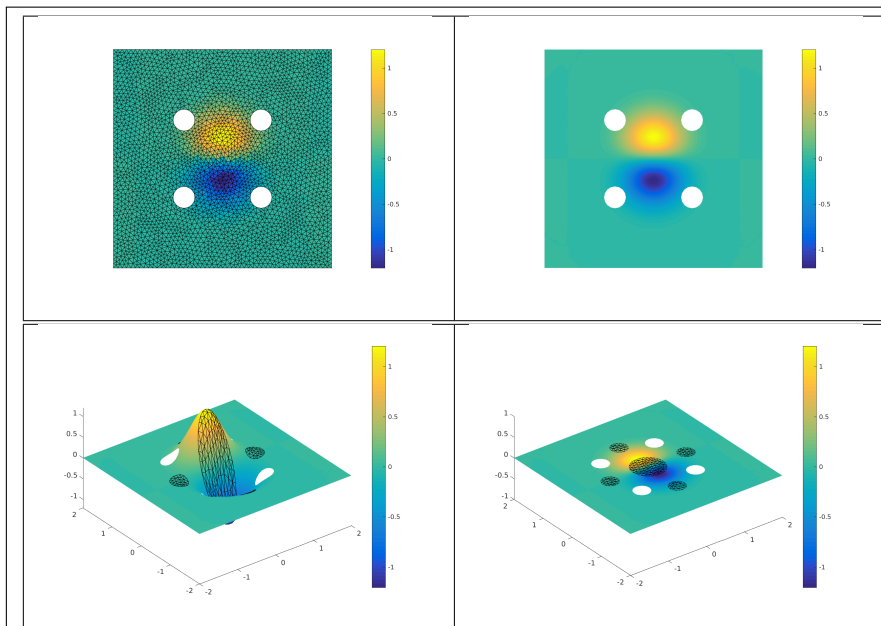
- `'d'` : to specify the dimension of the simplices elements (default : `Th.d`)
- `'labels'` : to select the labels of the elements to display data,
- `'plan'` : if true, (default : false)

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.



```

meshfile=gmsl.buildmesh2d('condenser11',25,'verbose',0);
Th=siMesh(meshfile);
u=Th.eval(@(x,y) 5*exp(-3*(x.^2+y.^2)).*cos(x).*sin(y));
figure(1)
Th.plotVal(u)
axis off;axis equal;
colorbar
figure(2)
Th.plotVal(u)
axis off;axis equal;
shading interp;colorbar

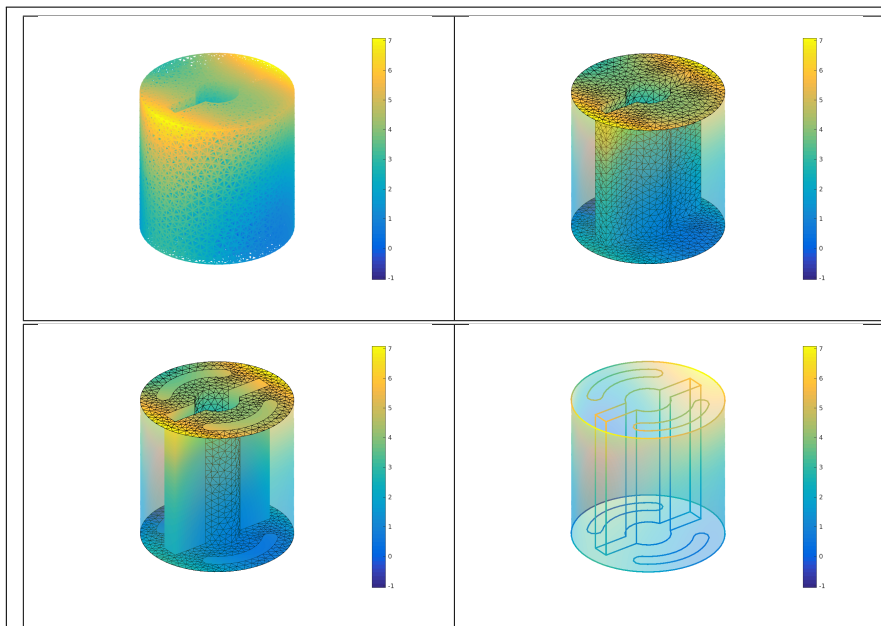
figure(3)
Th.plotVal(u,'labels',[2:2:8,20],'FaceColor','interp')
view(3);hold on;
Th.plotVal(u,'labels',10,'FaceColor','interp','EdgeColor','none')
axis equal;colorbar

figure(4)
Th.plotVal(u,'labels',[2:2:8,20],'plan',true ...
,'FaceColor','interp')
view(3);hold on;
Th.plotVal(u,'labels',10,'plan',true, ...
,'FaceColor','interp','EdgeColor','none')
axis equal;colorbar

```

Listing 19: 2D mesh : plotVal function

**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.



```

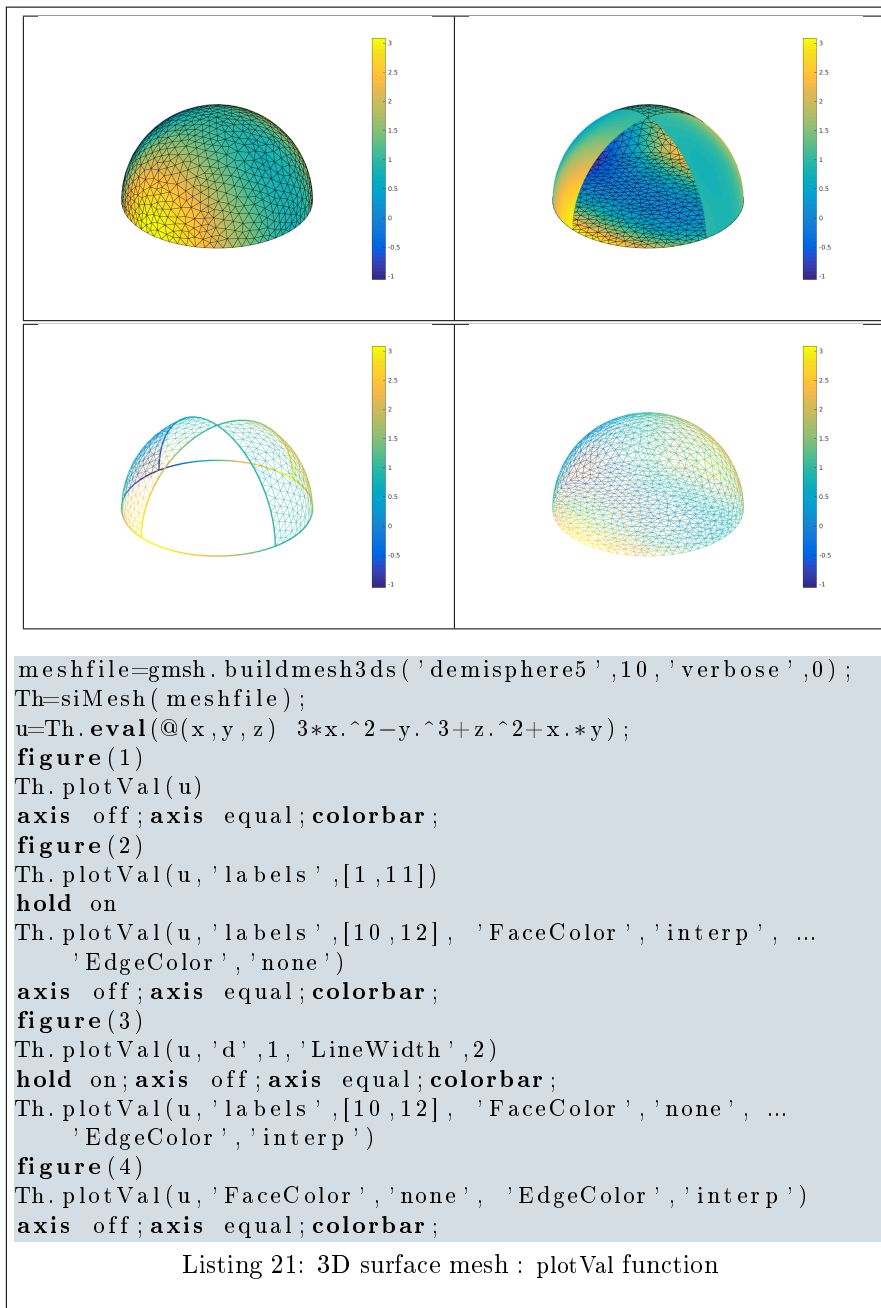
meshfile=gmsl.buildmesh3d('cylinderkey',10,'verbose',0);
Th=siMesh(meshfile);
u=Th.eval(@(x,y,z) 3*x.^2-y.^3+z.^2+x.*y);
figure(1)
Th.plotVal(u)
axis off;axis equal;colorbar
figure(2)
Th.plotVal(u,'d',2,'labels',[10,11,31,1000,1020,1021,2000,2020,2021])
hold on
Th.plotVal(u,'d',2,'labels',1,'FaceColor','interp',...
           'EdgeColor','none','FaceAlpha',0.4)
axis off;axis equal;colorbar
figure(3)
Th.plotVal(u,'d',2,'labels',1,'FaceColor','interp',...
           'EdgeColor','none','FaceAlpha',0.4)
hold on
Th.plotVal(u,'d',2,'labels',[10,11,1000,2000])
Th.plotVal(u,'d',2,'labels',[31,1020,1021,2020,2021],...
           'FaceColor','interp','EdgeColor','none')
axis off;axis equal;colorbar
figure(4)
Th.plotVal(u,'d',2,'labels',1,'FaceColor','interp',...
           'EdgeColor','none','FaceAlpha',0.4)
hold on
Th.plotVal(u,'d',1,'LineWidth',2)
axis off;axis equal;colorbar

```

Listing 20: 3D mesh : plotVal function

**3D surface example** The following example use the *.geo* file *demi sphere5.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.



### 3.1.4 function `PLOTISOLINES`

The method `PLOTISOLINES` 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

```
Th.plotIsolines(u)
Th.plotIsolines(u,Name,Value, ...)
```

## Description

`Th.plotVal(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`.

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

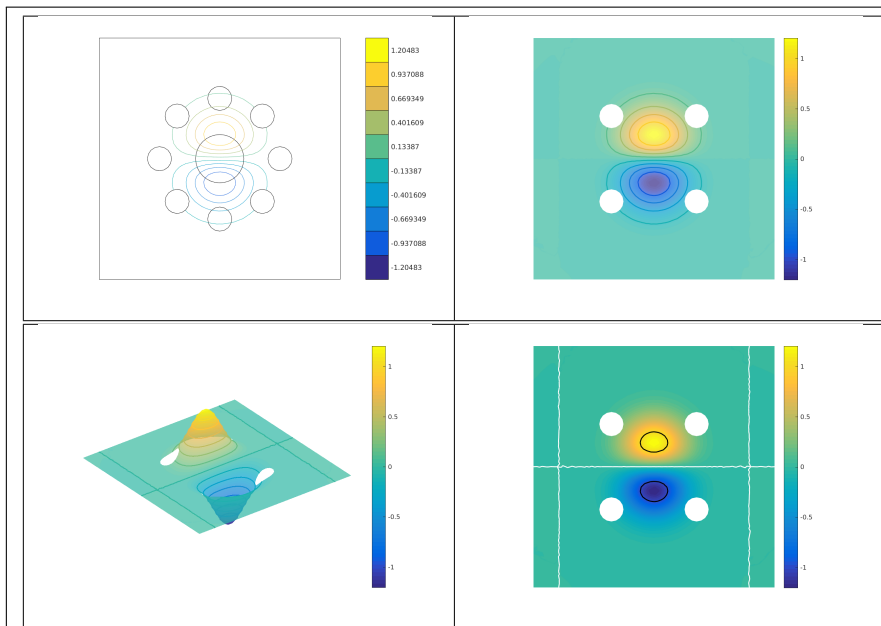
- `'niso'` : to specify the number of isolines (default : 10)
- `'isorange'` : to specify the list of isovalues (default : empty)
- `'isocolorbar'` : if true, colorbar with isovalues is drawn (default : false)
- `'format'` : to specify the format of the isovalues on the colorbar (default : '%g')
- `'labels'` : 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

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





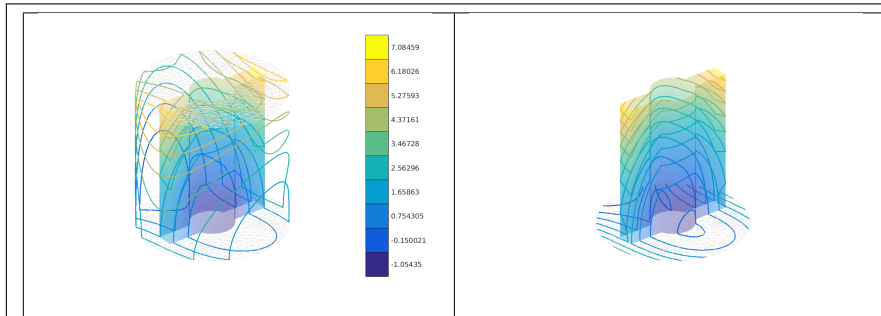
```

meshfile=gmshtoolbox.buildmesh2d('condenser11',25,'verbose',0);
Th=siMesh(meshfile);
u=Th.eval(@(x,y) 5*exp(-3*(x.^2+y.^2)).*cos(x).*sin(y));
figure(1)
Th.plot('d',1,'color','k')
hold on
Th.plotIsolines(u,'isocolorbar',true)
axis off;axis image;
figure(2)
Th.plotVal(u,'plan',true,'FaceAlpha',0.7)
shading interp;hold on
Th.plotIsolines(u,'plan',true,'LineWidth',1.5)
axis off;axis image;
colorbar
figure(3)
Th.plotVal(u,'FaceAlpha',0.7)
view(3)
shading interp;hold on
Th.plotIsolines(u,'niso',15,'LineWidth',1.5)
axis off;axis image;
colorbar
figure(4)
Th.plotVal(u,'plan',true)
shading interp;hold on
Th.plotIsolines(u,'isorange',0,'LineWidth',1.5,...
'color','w')
Th.plotIsolines(u,'isorange',[-1,1],'LineWidth',1.5,...
'color','k','plan',true)
axis off;axis image;colorbar

```

Listing 22: 2D mesh : plotIsolines function

**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.



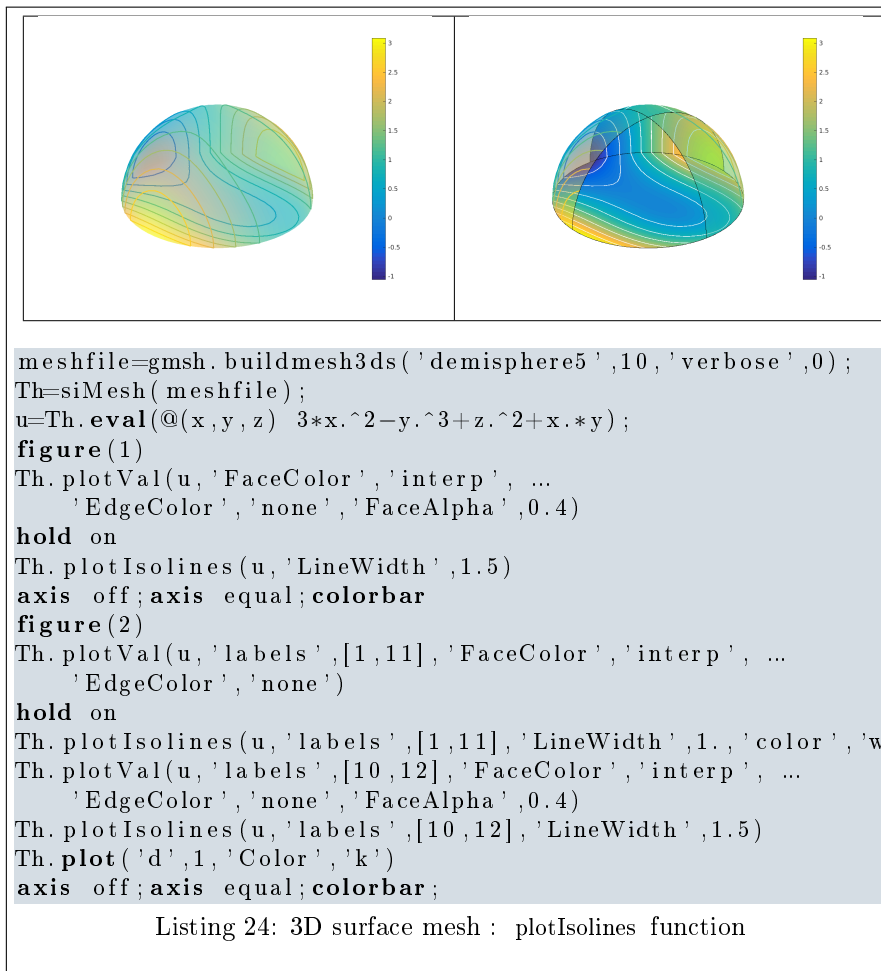
```

meshfile=gmshtoolbox.buildmesh3d('cylinderkey',10,'verbose',0);
Th=siMesh(meshfile);
u=Th.eval(@(x,y,z) 3*x.^2-y.^3+z.^2+x.*y);
figure(1)
Th.plotVal(u,'d',2,'labels',[10,11,31],'FaceColor','interp', ...
'EdgeColor','none','FaceAlpha',0.4)
hold on
Th.plot('d',2,'labels',[1000,1020,1021,2000,2020,2021], ...
'FaceColor','none','EdgeColor',0.9*[1,1,1])
Th.plotIsolines(u,'isocolorbar',true,'LineWidth',1.5)
view(3);axis off;axis equal;
figure(2)
Th.plotVal(u,'d',2,'labels',[10,11,31],'FaceColor','interp', ...
'EdgeColor','none','FaceAlpha',0.4)
hold on
Th.plot('d',2,'labels',[2000,2020,2021], ...
'FaceColor','none','EdgeColor',0.9*[1,1,1])
Th.plotIsolines(u,'labels',[10,11,31,2000,2020,2021],'LineWidth',1.5, ...
'niso',15)
axis off;axis equal;

```

Listing 23: 3D mesh : `plotIsolines` function

**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.



### 3.1.5 function SLICEMESH

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

#### Syntaxe

```

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

```

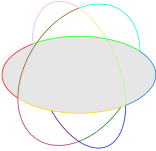

#### Description

`Th.slicemesh(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-SIMESH` 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.plot Val(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 `ball8.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.

	
<pre> meshfile=gmsl.buildmesh3d('ball8',20,'verbose',0); Th=siMesh(meshfile); figure(1) Th.plot('d',1,'LineWidth',1) hold on P=fc_tools.graphics.PlaneCoefs([0 0 0],[0 0 1]); Th.slicemesh(P,'FaceColor',0.9*[1 1 1]) axis off;axis image; figure(2) Th.plot('d',1,'LineWidth',1); hold on P2=fc_tools.graphics.PlaneCoefs([0 0 -0.5],[0 0 1]); Th.slicemesh(P2,'FaceColor',0.9*[1 1 1], ...     'EdgeColor','none') P3=fc_tools.graphics.PlaneCoefs([0 0 0.5],[0 0 1]); Th.slicemesh(P3,'FaceColor',0.9*[1 1 1], ...     'EdgeColor','none') axis off;axis image; </pre>	
<p>Listing 25: 3D mesh : slicemesh function</p>	