FC_SIMESH_MATPLOTLIB package, User's Guide *

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Abstract

The FC_SIMESH Python package allows to use simplices meshes generated from gmsh (in dimension 2 or 3) or an hypercube triangulation (in any dimension). The FC_SIMESH_MATPLOTLIB Python package presented in this report is an add-on to the FC_SIMESH Python package. A particular care was taken to the graphics representations of meshes and datas on meshes by using matplotlib package.

Contents

*Compiled with Python 3.6.0, packages FC_HYPERMESH-0.0.4, FC_OOGMSH-0.0.3, FC_TOOLS-0.0.9, FC_SIMESH-0.0.4and the plotting libraries MATPLOTLIB-2.0.0, FC_SIMESH_MATPLOTLIB-2.0.0

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1 Functions of the fc_simesh_matplotlib package

1.1 function PLOTMESH

The PLOTMESH function displays the mesh or parts of the mesh defined by an SIMESH object.

Syntaxe

```
siplt.plotmesh(Th,)
siplt.plotmesh(Th,Key=Value, ...)
```

Description

siplt.plotmesh(Th,) displays all the Th.d-dimensional simplices elements.

siplt.plotmesh(Th,Key=Value, ...) specifies function options using one or more Key,Value pair arguments. Options of first level are

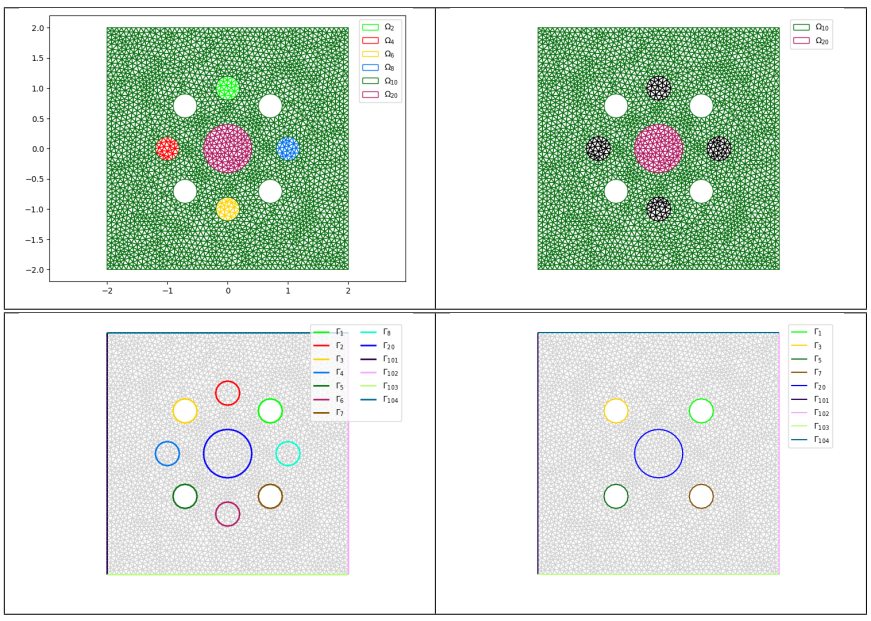
- `d` : to specify the dimension of the simplices elements (default : Th.d)
- `labels` : to select the labels of the elements to display,
- `color` : to specify the color of the displayed mesh elements. (default : use one color by displayed mesh elements),
- `legend` : add a legend to graph if True (default : False)

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 $d == 3$, Line3DCollection function is used
  - if $d == 2$, Poly3DCollection function is used
  - if $d == 1$, Line3DCollection function is used
  - if $d == 0$, ax.scatter function is used
- In dimension 2,
  - if $d == 2$, plt.triplot function is used,
  - if $d == 1$, ax.plot function is used
  - if $d == 0$, ax.plot function is used
- dimension 1, not yet implemented

1.1.1 2D example

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

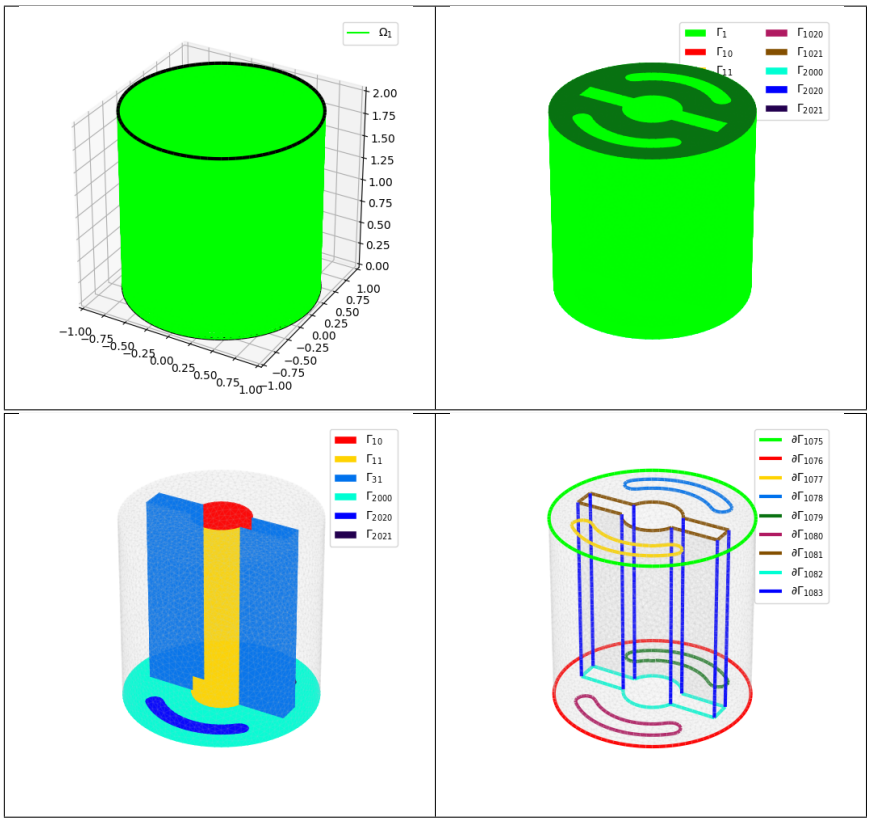


```
meshfile=gmsh.buildmesh2d('condenser11',25)
Th=siMesh(meshfile)
plt.figure(1)
siplt.plotmesh(Th,legend=True)
set_axes_equal()
plt.figure(2)
siplt.plotmesh(Th,labels=[10,20],legend=True)
siplt.plotmesh(Th,labels=[2,4,6,8],color='black') # ,'Linestyle',':')
plt.axis('off');set_axes_equal()
plt.figure(3)
siplt.plotmesh(Th,color='LightGray')
siplt.plotmesh(Th,d=1,legend=True,linewidth=2)
plt.axis('off');set_axes_equal()
plt.figure(4)
siplt.plotmesh(Th,color='LightGray')
siplt.plotmesh(Th,d=1,legend=True,labels=[1,3,5,7,20,101,102,103,104])
plt.axis('off');set_axes_equal()
```

Listing 1: 2D plot mesh

1.1.2 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.

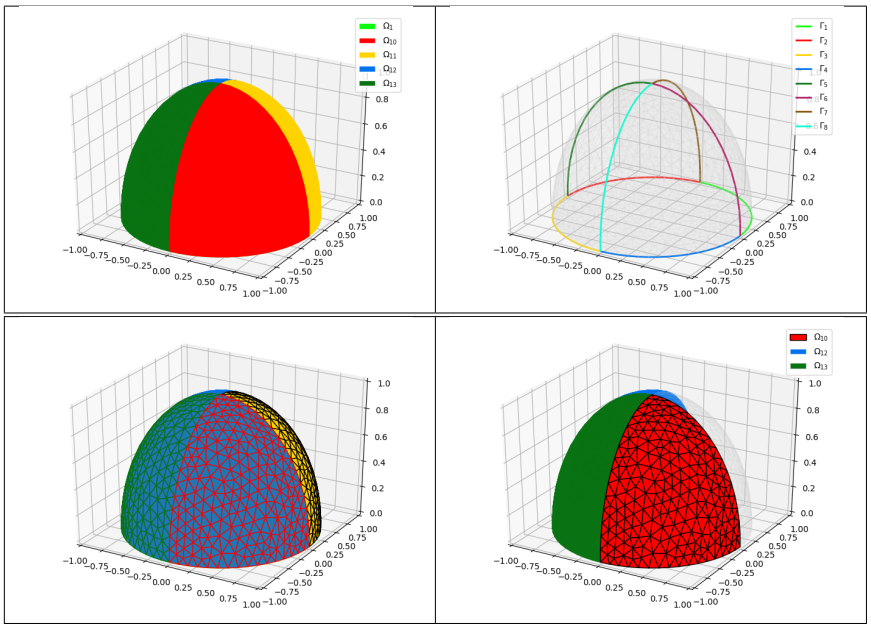



```
meshfile=gmsh.buildmesh3d('cylinderkey',15)
Th=siMesh(meshfile)
plt.figure(1)
siplt.plotmesh(Th,legend=True)
siplt.plotmesh(Th,d=1,color='black',linewidth=3)
set_axes_equal()
plt.figure(2)
siplt.plotmesh(Th,d=2,legend=True)
plt.axis('off'),set_axes_equal()
plt.figure(3)
siplt.plotmesh(Th,d=2,labels=[1,1000,1020,1021], color='LightGray', alpha=0.05)
siplt.plotmesh(Th,d=2,labels=[10,11,31,2000,2020,2021],legend=True,alpha=1)
plt.axis('off');set_axes_equal()
```

Listing 2: 3D plot mesh

1.1.3 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.



```
meshfile=gmsh.buildmesh3ds('demisphere5',20)
Th=siMesh(meshfile)
Th=siMesh(meshfile)
plt.figure(1)
siplt.plotmesh(Th,legend=True)
plt.figure(2)
siplt.plotmesh(Th,color='LightGray',alpha=0.1)
siplt.plotmesh(Th,d=1,legend=True,linewidth=2)
plt.figure(3)
siplt.plotmesh(Th,labels=[1,10,13,12],facecolor=None)
siplt.plotmesh(Th,labels=[11],edgecolor='black')
plt.figure(4)
siplt.plotmesh(Th,legend=True,labels=[10,13,12],edgecolor='black')
siplt.plotmesh(Th,labels=[1,11],color='LightGray',alpha=0.1)
```

Listing 3: 3D surface mesh : plot function

1.2 function PLOT

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

Syntaxe

```
siplt.plot(Th,u)
siplt.plot(Th,u,Key=Value, ...)
```

Description

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.

siplt.plot(Th,u,Key=Value, ...) specifies function options using one or more Key,Value pair arguments. Options of first level are

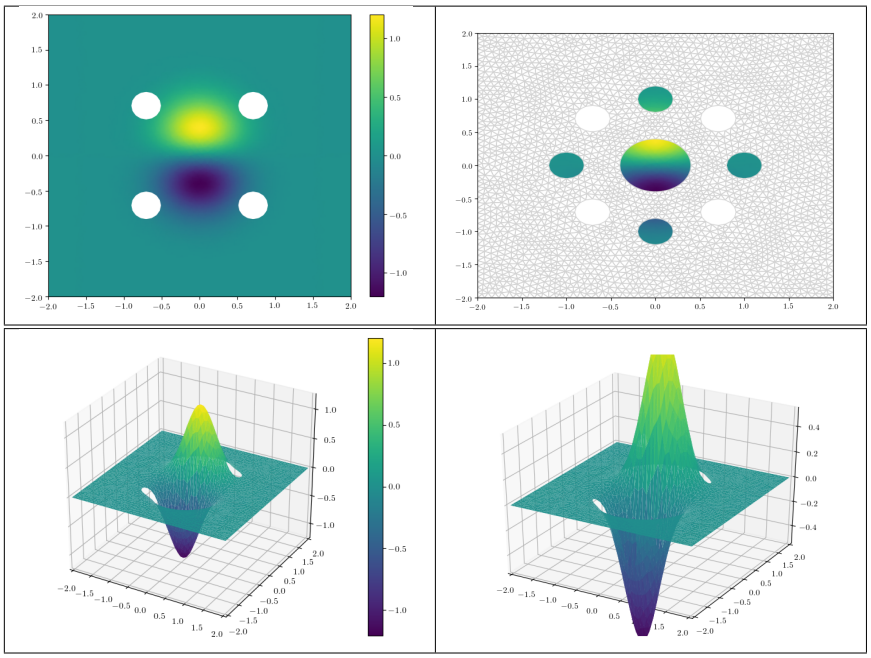
- `d` : to specify the dimension of the simplices elements (default : Th.d)
- `labels` : to select the labels of the elements to display data,
- `plane` : if True, (default : False)

The second level options 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,
  - if $d == 3$, scatter3D function is used
  - if $d == 2$, Poly3DCollection function is used.
  - if $d == 1$, Line3DCollection function is used.
- In dimension 2,
  - if $d == 2$, tripcolor function is used.
  - if $d == 1$, LineCollection function is used.
- Dimension 1 : not implemented.

1.2.1 2D example

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

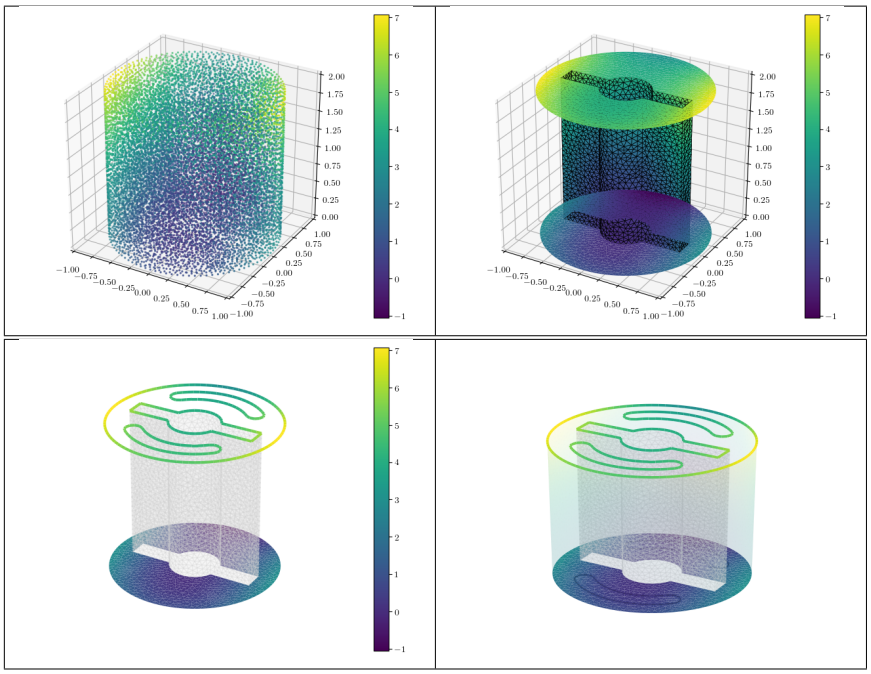


```
import numpy as np
meshfile=gmsh.buildmesh2d('condenser11',25)
Th=siMesh(meshfile)
u=Th.feval(lambda x,y: 5*np.exp(-3*(x**2+y**2))*np.cos(x)*np.sin(y))
plt.rcParams['text.usetex']=True
plt.rcParams['text.latex.unicode']=True
plt.ion()
fig=plt.figure(1)
siplt.plot(Th,u)
plt.colorbar()
plt.figure(2)
siplt.plot(Th,u,labels=[20,2,4,6,8])
siplt.plotmesh(Th,labels=10,color='LightGray')
plt.figure(3)
h=siplt.plot(Th,u,plane=False,colormap='viridis')
plt.colorbar(h)
plt.figure(4)
siplt.plot(Th,u,labels=[10,20], plane=False,colormap='viridis')
siplt.plot(Th,u,labels=[2,4,6,8], plane=False)
plt.show()
```

Listing 4: 2D mesh : plot function

1.2.2 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.

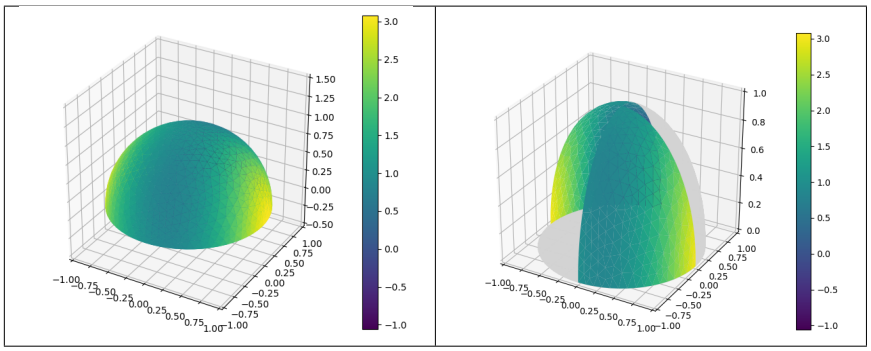


```
meshfile=gmsh.buildmesh3d('cylinderkey',15)
Th=siMesh(meshfile)
plt.close('all')
plt.ion()
plt.rcParams['text.usetex']=True
plt.rcParams['text.latex.unicode']=True
plt.close('all')
u=Th.feval(lambda x,y,z: 3*x**2-y**3+z**2+x*y)
fig=plt.figure(1)
#ax = fig.gca( projection='3d')
h=siplt.plot(Th,u,s=2)
plt.colorbar(h)
plt.figure(2)
h2=siplt.plot(Th,u,d=2,labels=[1000,1020,1021,2000,2020,2021])
siplt.plot(Th,u,d=2,labels=[10,11,31],edgecolor='black',linewidth=0.5)
plt.colorbar(h2)
plt.figure(3)
h2=siplt.plot(Th,u,d=2,labels=[2000,2020,2021])
h1=siplt.plot(Th,u,d=1,labels=[1075,1077,1078,1081],linewidth=3)
siplt.plotmesh(Th,d=2,labels=[10,11,31],color='LightGray',alpha=0.2)
plt.gca().set_axis_off()
plt.colorbar(h1)
plt.figure(4)
siplt.plot(Th,u,d=2,labels=[1],alpha=0.1)
siplt.plot(Th,u,d=2,labels=[2000,2020,2021])
siplt.plot(Th,u,d=1,labels=[1075,1077,1078,1081],linewidth=3)
siplt.plotmesh(Th,d=2,labels=[10,11,31],color='LightGray',alpha=0.2)
siplt.plotmesh(Th,d=1,labels=[1080,1079],color='black',linewidth=2)
plt.gca().set_axis_off()
```

Listing 5: 3D mesh : plot function

1.2.3 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.



```
meshfile=gmsh.buildmesh3ds('demisphere5',30)
Th=siMesh(meshfile)
u=Th.feval(lambda x,y,z: 3*x**2-y**3+z**2+x*y)
plt.figure(1)
h=siplt.plot(Th,u)
set_axes_equal()
plt.colorbar(h)
plt.figure(2)
h2=siplt.plot(Th,u,labels=[10,12])
siplt.plotmesh(Th,labels=[1,11],color='LightGray',linewidth=0.5)
plt.colorbar(h2)
```

Listing 6: 3D surface mesh : plot function

1.3 function PLOTISO

The PLOTISO function 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.

Syntaxe

```
siplt.plotiso(Th,u)
siplt.plotiso(Th,u,Key=Value, ...)
```

Description

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

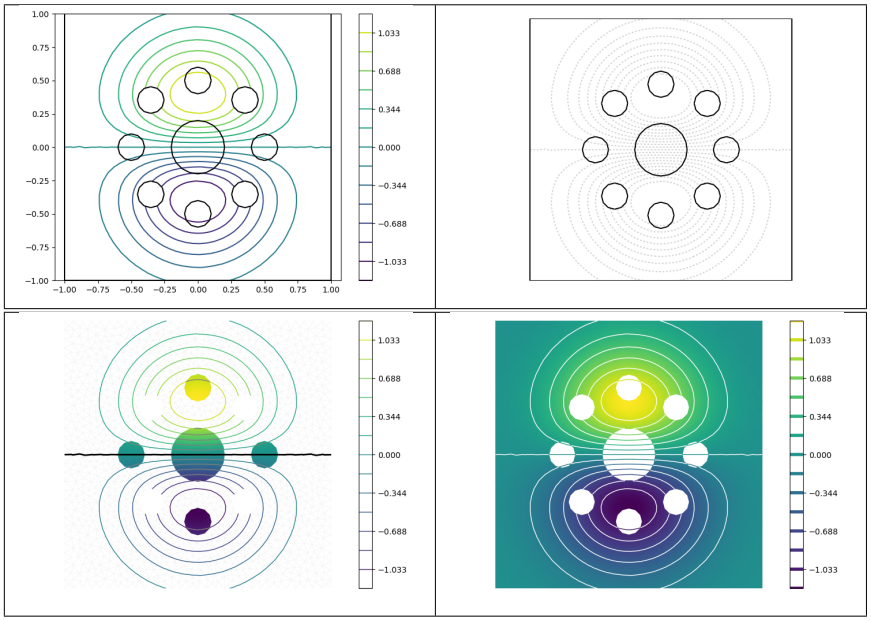
siplt . plotiso (Th,u,key=value, ...) specifies function options using one or more key,value pair arguments. Options of first level are

- `contours` : to specify the number of isolines (default : 10) or a list/numpy array of isovalues (default : empty)
- `labels` : to select the labels of the elements to display data,
- `colormap` : to specify the name of the colormap to use (default : 'viridis'))
- `color` : to specify one color for all isolines (default : None))

The second level options are the options of the plt . tricontour which we use to draw the isovalues.

1.3.1 2D example

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



```
meshfile=gmsh.buildmesh2d('condenser11',15)
Th=siMesh(meshfile)
u=Th.feval(lambda x,y: 5*np.exp(-3*(x**2+y**2))*np.cos(x)*np.sin(y))
plt.close('all')
plt.ion()
DisplayFigures(nfig=4)
fig=plt.figure(1)
siplt.plotiso(Th,u,niso=15)
siplt.plotmesh(Th,d=1,color='Black')
set_axes_equal()
plt.colorbar()
fig=plt.figure(2)
isos=np.linspace(-1,1,21)
siplt.plotiso(Th,u,niso=15,color='LightGray', isorange=isos,linestyles=':')
siplt.plotmesh(Th,d=1,color='Black')
plt.axis('off');set_axes_equal()
fig=plt.figure(3)
siplt.plotiso(Th,u,labels=10,niso=15,linewidths=1)
plt.colorbar()
siplt.plotmesh(Th,labels=10,color='LightGray',linewidth=1,alpha=0.05)
siplt.plotiso(Th,u,labels=[2,4,6,8,20],niso=15,color='Gray',linewidths=1)
siplt.plot(Th,u,labels=[2,4,6,8,20])
siplt.plotiso(Th,u,isorange=0,color='Black',linewidths=2)
plt.axis('off');set_axes_equal()
fig=plt.figure(4)
siplt.plotiso(Th,u,labels=10,niso=15,linewidths=1,color='White')
siplt.plot(Th,u,labels=10)
siplt.plotiso(Th,u,labels=[2,4,6,8,20],niso=15,linewidths=1)
cb=plt.colorbar()
cb.lines[0].set_linewidth(4)
plt.axis('off');set_axes_equal()
```

Listing 7: 2D mesh : plotiso function

1.3.2 function QUIVER

The QUIVER function displays vector field datas on the mesh or parts of the mesh defined by an SIMESH object.

Syntaxe

```
siplt.quiver(Th,V)
siplt.quiver(Th,V,Key=Value, ...)
```

Description

siplt .quiver(Th,V) displays vector field V on each vertices of the d-dimensional simplices elements in dimension $d = 2$ or $d = 3$. The data V is an 2D-array numpy array of size *dim*-by-Th.nq .

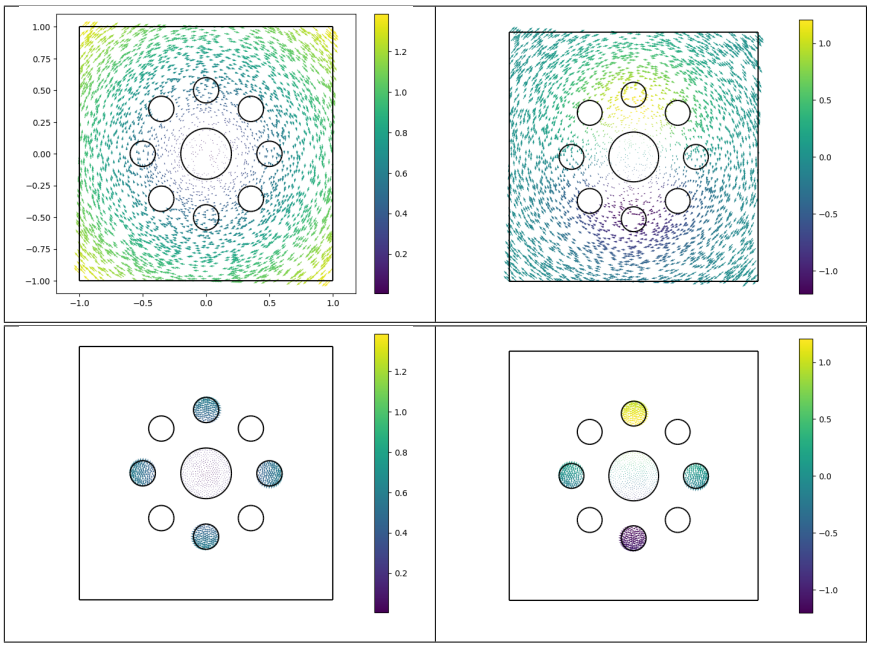
siplt .quiver(Th,V,Key=Value, ...) specifies function options using one or more Key,Value pair arguments. Options of first level are

- `labels` : to select the labels of the elements to display data,
- `scalars` : to set quivers color to a numpy array of size Th.nq (default : empty and use colors of the mesh elements).
- `color` : to specify one color for all quivers. By default colorized with the Euclidian norm of the vectors.

For key/value pairs, one could also used those of the plt.quiver function in dimension 2 and mpl_toolkits.mplot3d.quiver function in dimension 3

1.3.3 2D example

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

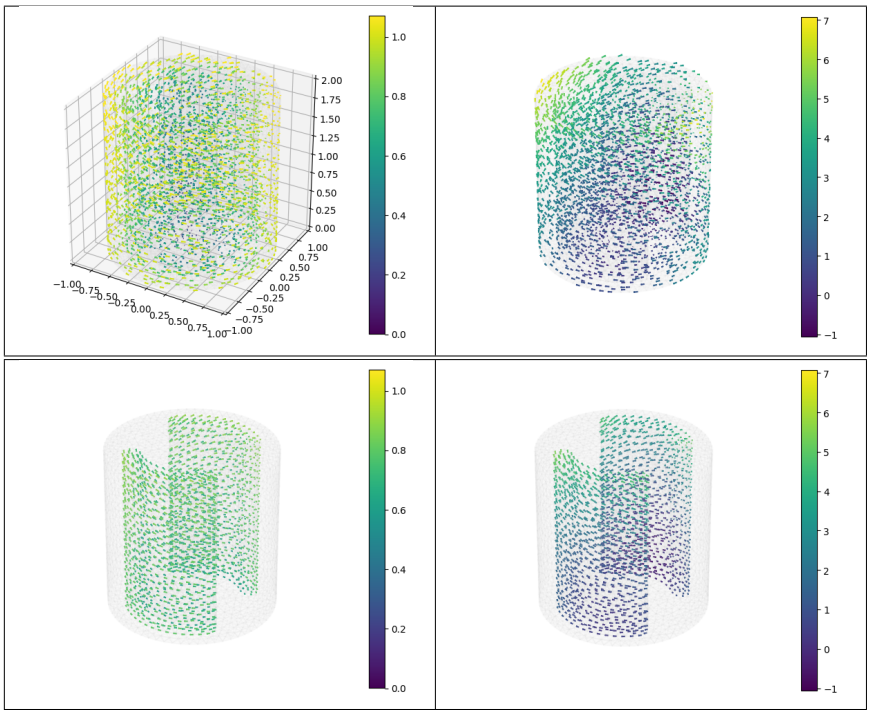


```
import numpy as np
meshfile=gmsh.buildmesh2d('condenser11',50)
Th=siMesh(meshfile)
u=Th.feval(lambda x,y: 5*np.exp(-3*(x**2+y**2))*np.cos(x)*np.sin(y))
w=[lambda x,y: y*np.cos(-(x**2+y**2)/10), lambda x,y: -x*np.cos(-(x**2+y**2)/10)]
W=np.array([Th.feval(w[0]),Th.feval(w[1])])
plt.figure(1)
siplt.quiver(Th,W,scale=50,nvec=3000)
siplt.plotmesh(Th,d=1,color='black')
set_axes_equal()
plt.colorbar()
plt.figure(2)
siplt.quiver(Th,W, scalars=u,scale=50,nvec=3000)
siplt.plotmesh(Th,d=1,color='black')
plt.axis('off');set_axes_equal()
plt.colorbar()
plt.figure(3)
siplt.quiver(Th,W,labels=[2,4,6,8,20] ,nvec=1000, scale=50)
siplt.plotmesh(Th,d=1,color='black')
plt.axis('off');set_axes_equal()
plt.colorbar()
plt.figure(4)
siplt.quiver(Th,W,labels=[2,4,6,8,20], scalars=u, scale=50, nvec=1000)
siplt.plotmesh(Th,d=1,color='black')
plt.axis('off');set_axes_equal()
plt.colorbar()
```

Listing 8: 2D mesh : quiver function

1.3.4 3D example

The following example use the *.geo* file `cylinderkey03.geo` which is in the directory `geodir/3d` of the toolbox. This file contains description of a 3D mesh with simplices of dimensions 1, 2 and 3.

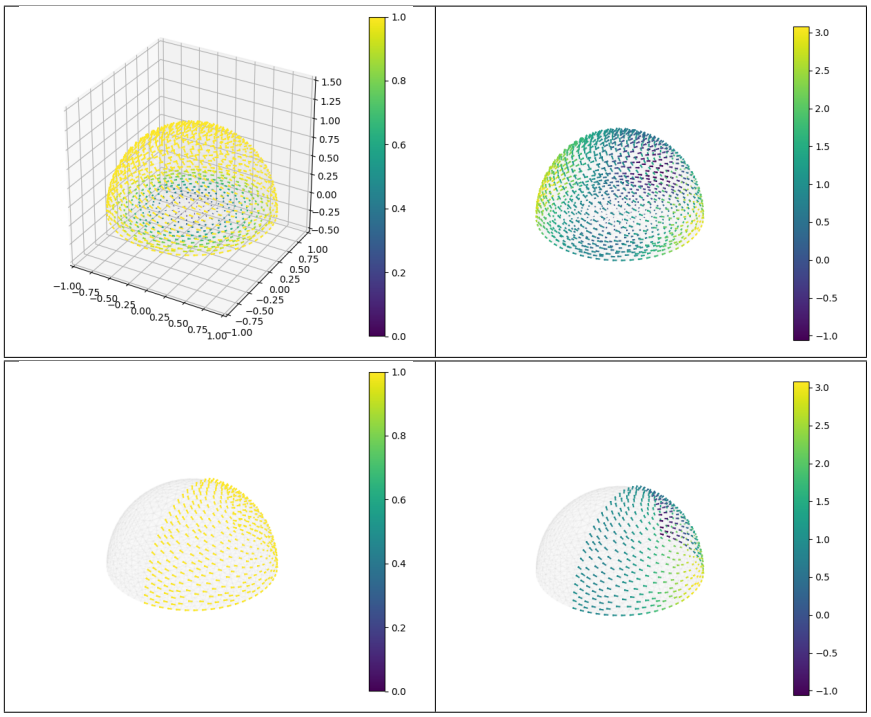


```
import numpy as np
meshfile=gmsh.buildmesh3d('cylinder3dom',10)
plt.close('all')
Th=siMesh(meshfile);
u=Th.feval(lambda x,y,z: 3*x**2-y**3+z**2+x*y)
w=[lambda x,y,z: y*np.cos(-(x**2+y**2)/10), lambda x,y,z:
    -x*np.cos(-(x**2+y**2)/10), lambda x,y,z: z/5]
W=np.array([Th.feval(w[0]),Th.feval(w[1]),Th.feval(w[2])])
scale=20
plt.figure(1)
sq=siplt.quiver(Th,W,nvec=3000,scale=scale)
siplt.plotmesh(Th,d=2,color='LightGray',alpha=0.05)
plt.colorbar(sq)
set_axes_equal()
plt.figure(2)
sq=siplt.quiver(Th,W,scalars=u, nvec=3000,scale=scale)
siplt.plotmesh(Th,d=2,color='LightGray',alpha=0.05)
plt.colorbar(sq)
plt.axis('off');set_axes_equal()
plt.figure(3)
sq=siplt.quiver(Th,W,labels=[10,11],nvec=3000,scale=scale)
siplt.plotmesh(Th,d=2,color='LightGray',alpha=0.05)
plt.axis('off');set_axes_equal()
plt.colorbar(sq)
plt.figure(4)
sq=siplt.quiver(Th,W,scalars=u, labels=[10,11],nvec=3000,scale=scale)
siplt.plotmesh(Th,d=2,color='LightGray',alpha=0.05)
plt.axis('off');set_axes_equal()
plt.colorbar(sq)
```

Listing 9: 3D mesh : quiver function

1.3.5 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.



```
import numpy as np
meshfile=gmsh.buildmesh3ds('demisphere5',30)
Th=siMesh(meshfile)
u=Th.feval(lambda x,y,z: 3*x**2-y**3+z**2+x*y)
w=[lambda x,y,z: y*np.cos(-(x**2+y**2)/10), lambda x,y,z:
    -x*np.cos(-(x**2+y**2)/10), lambda x,y,z: z]
W=np.array([Th.feval(w[0]),Th.feval(w[1]),Th.feval(w[2])])
scale=20
plt.figure(1)
sq=siplt.quiver(Th,W,nvec=3000,scale=scale)
siplt.plotmesh(Th,d=2,color='LightGray',alpha=0.05)
plt.colorbar(sq)
set_axes_equal()
plt.figure(2)
sq=siplt.quiver(Th,W,scalars=u, nvec=3000,scale=scale)
siplt.plotmesh(Th,d=2,color='LightGray',alpha=0.05)
plt.colorbar(sq)
plt.axis('off');set_axes_equal()
plt.figure(3)
sq=siplt.quiver(Th,W,labels=[10,11],nvec=3000,scale=scale)
siplt.plotmesh(Th,d=2,color='LightGray',alpha=0.05)
plt.axis('off');set_axes_equal()
plt.colorbar(sq)
plt.figure(4)
sq=siplt.quiver(Th,W,scalars=u, labels=[10,11],nvec=3000,scale=scale)
siplt.plotmesh(Th,d=2,color='LightGray',alpha=0.05)
plt.axis('off');set_axes_equal()
plt.colorbar(sq)
```

Listing 10: 3D surface mesh : quiver function