meshtools Matlab toolbox, User's Guide*

version 0.2.0

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Abstract

The experimental meshtools Matlab toolbox contains some meshes provided by `gmsh` when exporting the built mesh as a `.m` file. Theses meshes can be easily used in other Matlab codes for debugging or testing purpose.

0 Contents

1 Introduction

A mesh is given by its vertices/nodes array q and connectivity arrays, one by For demonstration purpose, some quadrangular and triangular/simplicial meshes are given in this package and stored in the `+fc_meshtools/data` directory. They can be load by using the function fc_meshtools.utils.read_data_f_file. Here are the kind of elements which can be found in the meshes present in this toolbox:

*LaTeX manual, revision 0.2.0, compiled with Matlab 2022a, and toolboxes `fc-meshtools`[0.2.0], `fc-tools`[0.1.0], `fc-bench`[0.1.4], `fc-amat`[0.1.4]

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- entity dimension $d = 0$, point,
- entity dimension $d = 1$, line,
- entity dimension $d = 2$, triangle, quadrangle,
- entity dimension $d = 3$, tetrahedron,hexahedron,prism,pyramid.

This toolbox was only tested on Ubuntu 24.04.1 with Matlab R2022a.

2 Installation

2.1 Installation automatic, all in one (recommanded)

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

mfc_meshtools_install.m

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

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

```
>> cd ~/Matlab
>> mfc_meshtools_install
```

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

```
Parts of the <fc-meshtools> Matlab toolbox.
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1- Downloading and extracting the toolboxes
2- Setting the <fc-meshtools> toolbox
Write in ~/Matlab/fc-meshtools-full/fc_meshtools-0.2.0/configure_loc.m ...
3- Using toolboxes :
   ->             fc-tools : 0.1.0
   ->             fc-bench : 0.1.4
   ->              fc-amat : 0.1.4
 with          fc-meshtools : 0.2.0
*** Using instructions
   To use the <fc-meshtools> toolbox:
   addpath('~/Matlab/fc-meshtools-full/fc_meshtools-0.2.0')
   fc_meshtools.init()

   See ~/Matlab/mfc_meshtools_set.m
```

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

```
>> addpath('~/Matlab/fc-meshtools-full/fc-meshtools-0.2.0')
>> fc_meshtools.init()
```

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

```
Try to use default parameters!
 Use fc_tools.configure to configure.
Write in ~/Matlab/fc-meshtools-full/fc_tools-0.1.0/configure_loc.m ...
Try to use default parameters!
 Use fc_bench.configure to configure.
Write in ~/Matlab/fc-meshtools-full/fc_bench-0.1.4/configure_loc.m ...
Try to use default parameters!
 Use fc_amat.configure to configure.
Write in ~/Matlab/fc-meshtools-full/fc_amat-0.1.4/configure_loc.m ...
Using fc_meshtools[0.2.0] with fc_tools[0.1.0], fc_bench[0.1.4], fc_amat[0.1.4].
```

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

```
Using fc_meshtools[0.2.0] with fc_tools[0.1.0], fc_bench[0.1.4], fc_amat[0.1.4].
```

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

`~/Matlab/fc-meshtools-full`

3 Functions

3.1 function fc_meshtools.utils.read_data_m_file

reads a .m file generated by GMSH and stored in the data directory of the toolbox.

Syntaxe

```
msh=fc_meshtools.utils.read_data_m_file.read_data_m_file(Key,Value,
    ...)
```

Description

msh=fc_meshtools.utils.read_data_m_file.read_data_m_file(Key,Value, ...)

Optional key/value pairs could be used. The keys are:

- 'dim' : to specify space dimension (2 or 3). Default 2.
- 'd' : to specify the dimension of mesh elements (2 or 3 with d<=dim. Default 2.
- 'quad' : if true select a quadrangular mesh otherwise a triangular mesh. Default false.
- 'small' : if true select the small mesh otherwise a biggest mesh. Default true.
- 'verbose' : if true display .m mesh file to be read. Default true.

Returns msh a structure with certain fields depending on the type of elements present in the mesh. Here are the fields always present in the msh structure:

- nbNod : number of nodes,
- POS : nbNod-by-dim nodes array.
- MIN : [xmin,ymin] in 2D or [xmin,ymin,zmin] in 3D.
- MAX : [xmax,ymax] in 2D or [xmax,ymax,zmax] in 3D.
- LINES :nbLines-by-3 array, LINES(:,1:2) is the connectivity array and LINES(:,3) are the line tags.

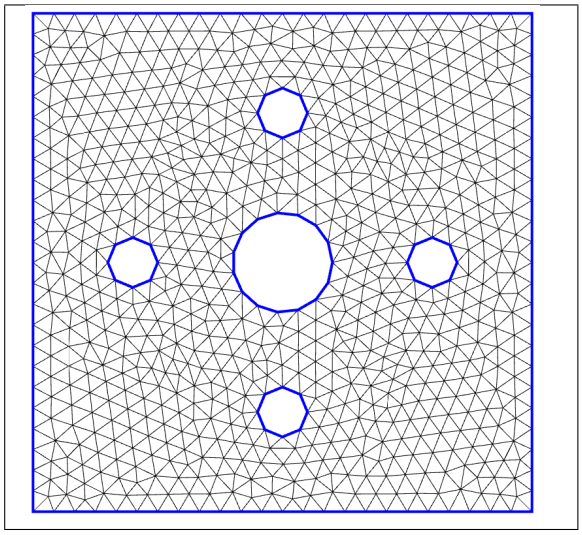
Here are the fields which can be found in structure:

- PNT : nbPoints-by-2 array (nbPoints<=nbNod), PNT(i,1) is the index in POS array of the point with tag PNT(i,2).
- TRIANGLES : nbTriangles-by-4 array, TRIANGLES(:,1:3) is the connectivity array and TRIANGLES(:,4) are the triangle tags.
- QUADS : nbQuadrangles-by-5 array, QUADS(:,1:4) is the connectivity array and QUADS(:,5) are the quadrangle tags.
- TETS : nbTetrahedra-by-5 array, TETS(:,1:4) is the connectivity array and TETS(:,5) are the tetrahedron tags.
- HEXAS : nbHexahedra-by-9 array, HEXAS(:,1:8) is the connectivity array and HEXAS(:,9) are the hexahedron tags.
- PYRAMIDS : nbPyramids-by-6 array, PYRAMIDS(:,1:5) is the connectivity array and PYRAMIDS(:,6) are the pyramid tags.
- PRISMS : nbPrisms-by-7 array, PRISMS(:,1:6) is the connectivity array and PRISMS(:,7) are the prism tags.

Listing 1: Using fc_meshtools.utils.read_data_m_file function (see fc_meshtools.demos.simplicial_2D01). Below, the text output is given as well as the figure obtained.

```
msh=fc_meshtools.utils.read_data_m_file('d',2,'dim',2,'quad',false,'small',true);
fc_tools.utils.disp_object(msh)
patch('vertices',msh.POS,'faces',msh.TRIANGLES(:,1:3),'facecolor','None','edgecolor','k')
patch('vertices',msh.POS,'faces',msh.LINES(:,1:2),'edgecolor','b','linewidth',2)
axis equal;axis off
```

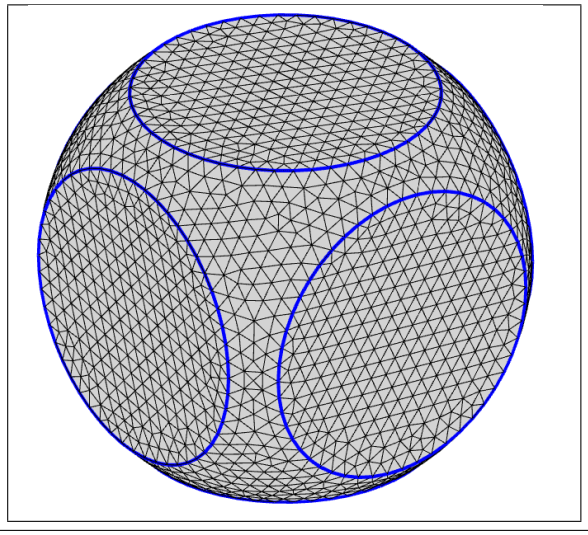
```
loading GMSH .m file : <fc-meshtools>/data/condenser110C_small.m
  struct with fields :
       nbNod: 801 double
         POS: (801x2 double)
         MAX: [ 1 1 ] (1x2 double)
         MIN: [ -1 -1 ] (1x2 double)
       LINES: (143x3 double)
   TRIANGLES: (1467x4 double)
```



Listing 2: Using fc_meshtools.utils.read_data_m_file function (see fc_meshtools.demos.simplicial_3Ds01). Below, the text output is given as well as the figure obtained.

```
msh=fc_meshtools.utils.read_data_m_file('d',2,'dim',3,'quad',false,'small',true);
fc_tools.utils.disp_object(msh)
color=fc_tools.graphics.xcolor.val2rgb('lightgray');
patch('vertices',msh.POS,'faces',msh.TRIANGLES(:,1:end-1),'facecolor',color,'edgecolor','k')
hold on;axis equal;axis off;view(3)
%patch('vertices',msh.POS,'faces',msh.LINES(:,1:end-1),'edgecolor','b','linewidth',2)
fc_meshtools.utils.plot_edges(msh.POS,msh.LINES(:,1:2),'color','b','linewidth',2)
```

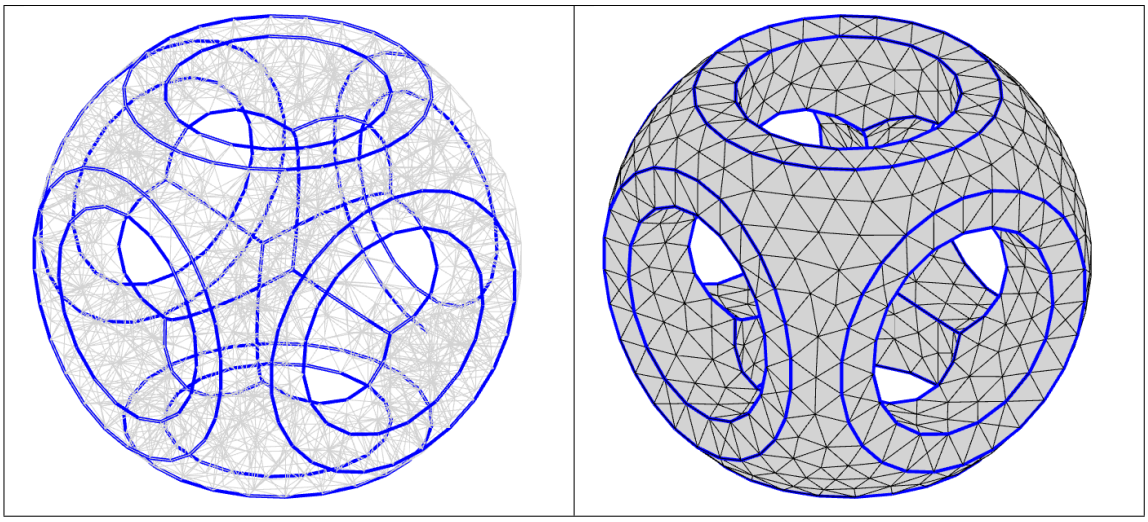
```
loading GMSH .m file : <fc-meshtools>/data/diceOC_small.m
  struct with fields :
       nbNod: 2423 double
         POS: (2423x3 double)
         MAX: [ 0.5 0.5 0.5 ] (1x3 double)
         MIN: [ -0.5 -0.5 -0.5 ] (1x3 double)
       LINES: (312x3 double)
   TRIANGLES: (4842x4 double)
```



Listing 3: Using fc_meshtools.utils.read_data_m_file function (see fc_meshtools.demos.simplicial_3D01). Below, the text output is given as well as the figures obtained.

```
msh=fc_meshtools.utils.read_data_m_file('d',3,'dim',3,'quad',false,'small',true);
fc_tools.utils.disp_object(msh)
color=fc_tools.graphics.xcolor.val2rgb('lightgray');
figure(1)
patch('vertices',msh.POS,'faces',msh.TETS(:,1:end-1),'facecolor','None','edgecolor',color)
hold on
fc_meshtools.utils.plot_edges(msh.POS,msh.LINES(:,1:2),'color','b','linewidth',2)
axis equal;axis off;view(3)
figure(2)
patch('vertices',msh.POS,'faces',msh.TRIANGLES(:,1:end-1),'facecolor',color,'edgecolor','k')
hold on
fc_meshtools.utils.plot_edges(msh.POS,msh.LINES(:,1:2),'color','b','linewidth',2)
axis equal;axis off;view(3)
```

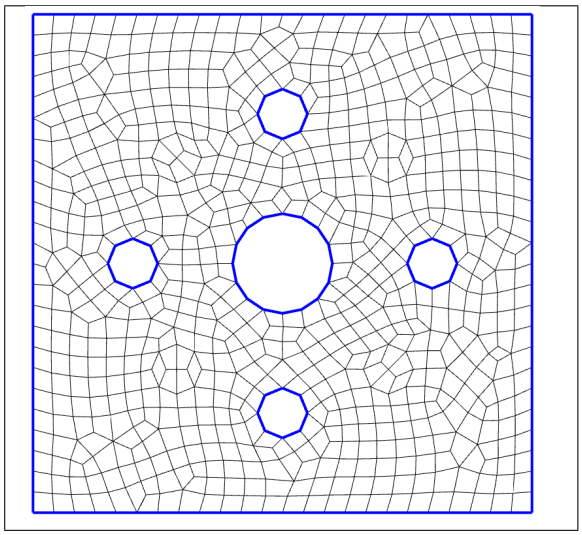
```
loading GMSH .m file : <fc-meshtools>/data/holeddice0C_small.m
  struct with fields :
      nbNod: 839 double
        POS: (839x3 double)
        MAX: [ 0.5 0.5 0.5 ] (1x3 double)
        MIN: [ -0.5 -0.5 -0.5 ] (1x3 double)
      LINES: (329x3 double)
  TRIANGLES: (1590x4 double)
       TETS: (2421x5 double)
```



Listing 4: Using fc_meshtools.utils.read_data_m_file function (see fc_meshtools.demos.quad_2D01). Below, the text output is given as well as the figure obtained.

```
msh=fc_meshtools.utils.read_data_m_file('d',2,'dim',2,'quad',true,'small',true);
fc_tools.utils.disp_object(msh)
patch('vertices',msh.POS,'faces',msh.QUADS(:,1:end-1),'facecolor','None','edgecolor','k')
hold on
fc_meshtools.utils.plot_edges(msh.POS,msh.LINES(:,1:end-1),'color','b','linewidth',2)
axis equal;axis off
```

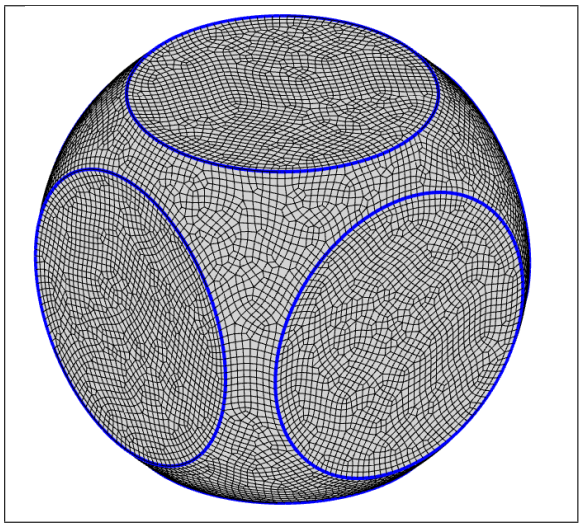
```
loading GMSH .m file : <fc-meshtools>/data/condenser110C_quad_small.m
  struct with fields :
    nbNod: 790 double
      POS: (790x2 double)
      MAX: [ 1 1 ] (1x2 double)
      MIN: [ -1 -1 ] (1x2 double)
    LINES: (144x3 double)
    QUADS: (722x5 double)
```



Listing 5: Using fc_meshtools.utils.read_data_m_file function (see fc_meshtools.demos.quad_3Ds01). Below, the text output is given as well as the figure obtained.

```
msh=fc_meshtools.utils.read_data_m_file('d',2,'dim',3,'quad',true,'small',false);
fc_tools.utils.disp_object(msh)
color=fc_tools.graphics.xcolor.val2rgb('lightgray');
patch('vertices',msh.POS,'faces',msh.QUADS(:,1:4),'facecolor',color,'edgecolor','k')
hold on
fc_meshtools.utils.plot_edges(msh.POS,msh.LINES(:,1:2),'color','b','linewidth',2)
axis equal;axis off;view(3)
```

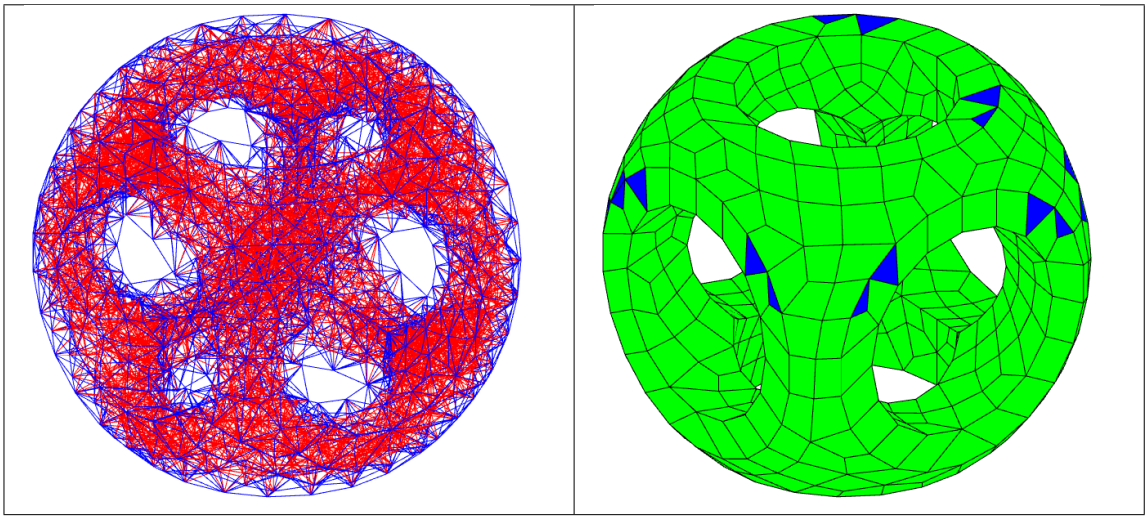
```
loading GMSH .m file : <fc-meshtools>/data/diceOC_quad.m
  struct with fields :
    nbNod: 14076 double
      POS: (14076x3 double)
      MAX: [ 0.5 0.5 0.5 ] (1x3 double)
      MIN: [ -0.5 -0.5 -0.5 ] (1x3 double)
    LINES: (768x3 double)
    QUADS: (14074x5 double)
```



Listing 6: Using fc_meshtools.utils.read_data_m_file function (see fc_meshtools.demos.quad_3D01). Below, the text output is given as well as the figures obtained.

```
msh=fc_meshtools.utils.read_data_m_file('d',3,'dim',3,'quad',true,'small',true);
fc_tools.utils.disp_object(msh)
colors=fc_tools.graphics.selectColors(3);
figure(1)
FacesTETS=fc_meshtools.utils.get_faces(msh.TETS(:,1:end-1),'tetrahedron');
patch('vertices',msh.POS,'faces',FacesTETS,'facecolor','None','edgecolor','r')
FacesPYR=fc_meshtools.utils.get_faces(msh.PYRAMIDS(:,1:end-1),'pyramid');
patch('vertices',msh.POS,'faces',FacesPYR,'facecolor','None','edgecolor','b')
axis equal;axis off;view(3)
figure(2)
patch('vertices',msh.POS,'faces',msh.TRIANGLES(:,1:end-1),'facecolor',colors(1,:),'edgecolor','k')
patch('vertices',msh.POS,'faces',msh.QUADS(:,1:end-1),'facecolor',colors(2,:),'edgecolor','k')
axis equal;axis off;view(3)
```

```
loading GMSH .m file : <fc-meshtools>/data/holeddiceOC_quad_small.m
  struct with fields :
       nbNod: 3129 double
         POS: (3129x3 double)
         MAX: [ 0.5 0.5 0.5 ] (1x3 double)
         MIN: [ -0.5 -0.5 -0.5 ] (1x3 double)
       LINES: (306x3 double)
   TRIANGLES: (30x4 double)
       QUADS: (722x5 double)
        TETS: (14656x5 double)
    PYRAMIDS: (722x6 double)
```



3.2 function `fc_meshtools.utils.read_gmsh_m_file`

reads a `.m` file generated by GMSH.

Syntaxe

```
msh=fc_meshtools.utils.read_data_m_file.read_gmsh_m_file(filename)
```

Description

msh=fc_meshtools.utils.read_gmsh_m_file.read_gmsh_m_file(filename)

Returns msh a structure with certain fields depending on the type of elements present in the mesh. Here are the fields always present in the msh structure:

- nbNod : number of nodes,
- POS : nbNod-by-dim nodes array.
- MIN : [xmin,ymin] in 2D or [xmin,ymin,zmin] in 3D.
- MAX : [xmax,ymax] in 2D or [xmax,ymax,zmax] in 3D.
- LINES :nbLines-by-3 array, LINES(:,1:2) is the connectivity array and LINES(:,3) are the line tags.

Here are the principal fields which can be found in the structure:

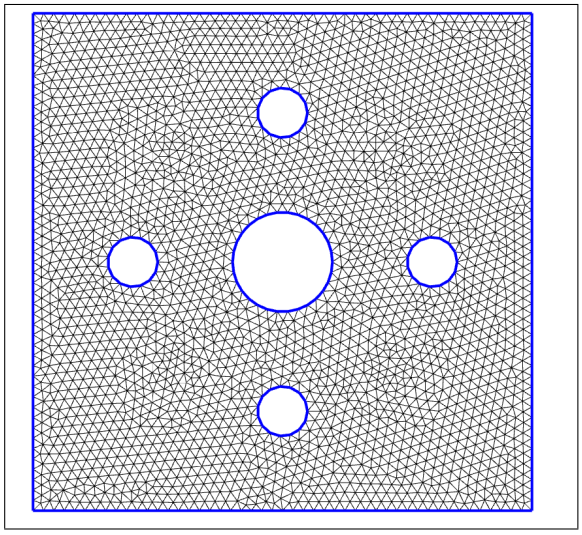
- PNT : nbPoints-by-2 array (nbPoints<=nbNod), PNT(i,1) is the index in POS array of the point with tag PNT(i,2).
- TRIANGLES : nbTriangles-by-4 array, TRIANGLES(:,1:3) is the connectivity array and TRIANGLES(:,4) are the triangle tags.
- QUADS : nbQuadrangles-by-5 array, QUADS(:,1:4) is the connectivity array and QUADS(:,5) are the quadrangle tags.
- TETS : nbTetrahedra-by-5 array, TETS(:,1:4) is the connectivity array and TETS(:,5) are the tetrahedron tags.
- HEXAS : nbHexahedra-by-9 array, HEXAS(:,1:8) is the connectivity array and HEXAS(:,9) are the hexahedron tags.
- PYRAMIDS : nbPyramids-by-6 array, PYRAMIDS(:,1:5) is the connectivity array and PYRAMIDS(:,6) are the pyramid tags.
- PRISMS : nbPrisms-by-7 array, PRISMS(:,1:6) is the connectivity array and PRISMS(:,7) are the prism tags.

With an nth order mesh, other fields are present in the `.m` file: see the source file of GMSH `src/geo/GModelIO_MATLAB.cpp`

Listing 7: Using fc_meshtools.utils.**read_gmsh_m_file** function (see fc_meshtools.demos.read_gmsh_m_file_2D01). Below, the text output is given as well as the figure obtained.

```
env=fc_meshtools.environment();
filename=fullfile(env.data_dir,'condenser11OC.m');
msh=fc_meshtools.utils.read_gmsh_m_file(filename);
fc_tools.utils.disp_object(msh)
patch('vertices',msh.POS,'faces',msh.TRIANGLES(:,1:3),'facecolor','None','edgecolor','k')
hold on
fc_meshtools.utils.plot_edges(msh.POS,msh.LINES(:,1:end-1),'color','b','linewidth',2)
axis equal;axis off
```

```
struct with fields :
      nbNod: 2771 double
        POS: (2771x2 double)
        MAX: [ 1 1 ] (1x2 double)
        MIN: [ -1 -1 ] (1x2 double)
      LINES: (282x3 double)
  TRIANGLES: (5268x4 double)
```



3.3 function fc_meshtools.utils.get_faces

Returns the faces of all mesh elements of type geo and given by its connectivity array connect.

Syntaxe

```
Faces=fc_meshtools.utils.get_faces(connect,geo)
Faces=fc_meshtools.utils.get_faces(connect,geo,'unique',true)
```

Description

Faces=fc_meshtools.utils.get_faces(connect,geo)

- connect : is an nme-by-nv array with nme, the number of mesh elements, and nv the number of vertices of an element of type geo
- geo : type of mesh elements. Must be in

  {'triangle','quadrangle','tetrahedron','hexahedron','prism','pyramid'}

  The index order of the vertices of an element are those of `gmsh`.

The output Faces is an nf-by-m connectivity array where m is the maximum number of vertices by faces m:3 for triangle,tetrahedron, m:4 for quadrangle,hexahedron,prism,pyramid For prisms and pyramids, there are both triangular and quadrangular faces. The 3 indices for triangular faces with m==4, are in Faces(i,1:3) and we have Faces(i,4)==NaN.

An optional key/value pair could be used. The key is:

- 'unique': logical, if true the returned Faces are unique (always unique with line,triangle, quadrangle). Default false.

3.4 function fc_meshtools.utils.get_edges

Returns the edges of all mesh elements of type geo and given by its connectivity array connect.

Syntaxe

```
Edges=fc_meshtools.utils.get_edges(connect,geo)
Edges=fc_meshtools.utils.get_edges(connect,geo,'unique',true)
```

Description

Edges=fc_meshtools.utils.get_edges(connect,geo)

- connect : is an nme-by-nv array with nme, the number of mesh elements, and nv the number of vertices of an element of type geo
- geo : type of mesh elements. Must be in

  {'triangle','quadrangle','tetrahedron','hexahedron','prism','pyramid'}

  The index order of the vertices of an element are those of `gmsh`.

The output Edges is an ned-by-2 connectivity array where ned is the number of edges.

An optional key/value pair could be used. The key is:

- 'unique': logical, if true the returned Edges are unique. Default false.

3.5 function fc_meshtools.utils.plot_edges

Plots edges given by a vertex array vertices and a connectivity array connect

Syntaxe

```
fc_meshtools.utils.get_edges(vertices,connect, key,value, ...)
h=fc_meshtools.utils.get_edges(vertices,connect, key,value, ...)
```

Description

fc_meshtools.utils.get_edges(vertices,connect, key,value, ...

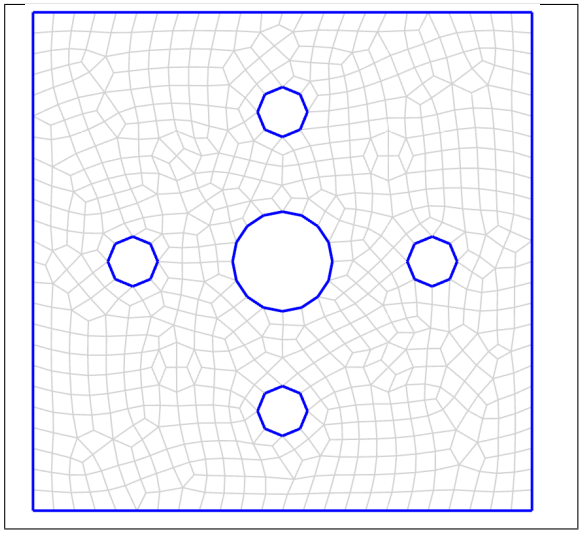
- vertices : nv-by-dim array, nv number of vertices, dim space dimension (2 or 3).
- connect : N-by-2 array with N, the number of edges, such that the two vertices of the i-th edges are vertices(connect(i,1),:) and vertices(connect(i,2),:) .

Optional key/value pairs are transfered to the plot3 function in dimension 3 or to the plot function in dimension 2.

If requested, the output value is that of plot or plot3 function.

Listing 8: Using fc_meshtools.utils.get_edges and fc_meshtools.utils.plot_edges and functions (see fc_meshtools.demos.quad_2D02).

```
msh=fc_meshtools.utils.read_data_m_file('d',2,'dim',2,'quad',true,'small',true);
fc_tools.utils.disp_object(msh)
Edges=fc_meshtools.utils.get_edges(msh.QUADS(:,1:end-1),'quadrangle','unique',true);
fc_meshtools.utils.plot_edges(msh.POS,Edges,'color','lightgray','linewidth',1)
hold on
fc_meshtools.utils.plot_edges(msh.POS,msh.LINES(:,1:end-1),'color','b','linewidth',2)
axis equal;axis off
```

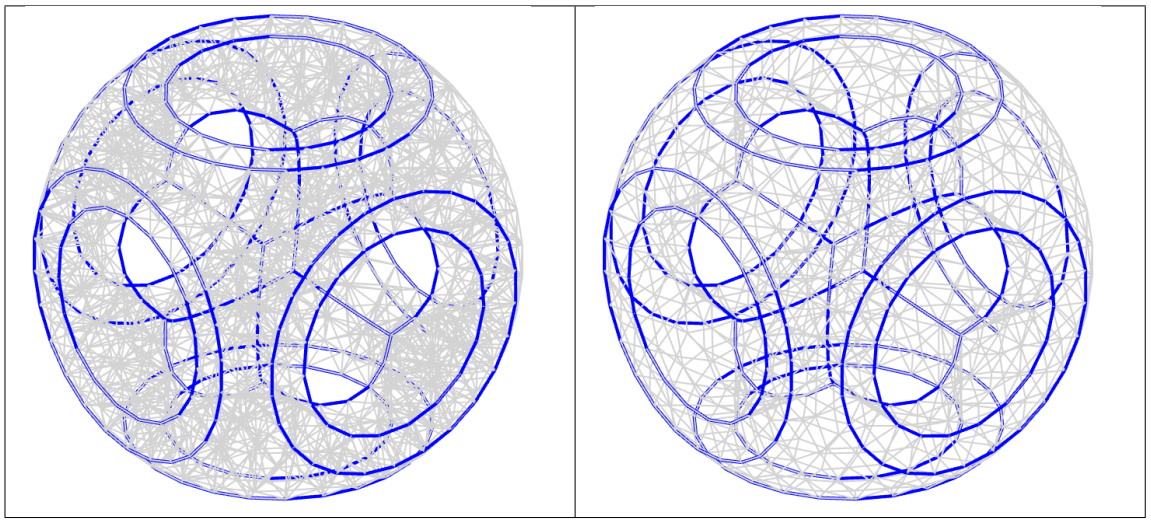


Listing 9: Using fc_meshtools.utils.get_edges and fc_meshtools.utils.plot_edges and functions (see fc_meshtools.demos.simplicial_3D02).

```
msh=fc_meshtools.utils.read_data_m_file('d',3,'dim',3,'quad',false,'small',true);
fc_tools.utils.disp_object(msh)

EdgesTETS=fc_meshtools.utils.get_edges(msh.TETS(:,1:end-1),'tetrahedron','unique',true);
figure(1)
fc_meshtools.utils.plot_edges(msh.POS,EdgesTETS,'color','lightgray','linewidth',1)
hold on;axis equal;axis off;view(3)
fc_meshtools.utils.plot_edges(msh.POS,msh.LINES(:,1:end-1),'color','b','linewidth',2)

EdgesTRI=fc_meshtools.utils.get_edges(msh.TRIANGLES(:,1:end-1),'triangle','unique',true);
figure(2)
fc_meshtools.utils.plot_edges(msh.POS,EdgesTRI,'color','lightgray','linewidth',1)
hold on;axis equal;axis off;view(3)
fc_meshtools.utils.plot_edges(msh.POS,msh.LINES(:,1:end-1),'color','b','linewidth',2)
```



3.6 function fc_meshtools.utils.get_local_mesh

Syntaxe Returns a local mesh associated with msh, a structure provided by a `.m` file generated with `gmsh`.

Description

function [q,me,L2G]=get_local_mesh(msh,type)

- msh : the structure obtain when loading a `.m` file generated by `gmsh`.
- type : one of the type of elements present in the msh structure as field. Could be 'LINES', 'TRIANGLES', 'QUADS', 'TETS', ...

An optional key/value pair can be used. The key is

- 'tags' : to select type of elements with tag in provided value.

Returns three arrays:

- 'q' : nodes array with dimension dim-by-nq.,
- 'me' : connectivity array of dimension m-by-nme (m: number of vertices by element, nme: number of type elements) associated with the array q. The vertices of the k-th type element are

$$q(:, me(k,1)), \ldots, q(:, me(k,m))$$

- 'L2G' : local to global index.

$$q(:, i) == msh.POS(L2G(i),:)'$$

One can refers to fc_meshtools.demos.get_local_mesh_* programs to see multiple usages. An example is given in Listing 10.

Listing 10: Using fc_meshtools.utils.**get_local_mesh** function (see fc_meshtools.demos.get_local_mesh_2D01). Below, the text output is given.

```
msh=fc_meshtools.utils.read_data_m_file('d',2,'dim',2,'quad',false,'small',true);
Stags=fc_meshtools.utils.get_tags(msh);

[q,me,L2G]=fc_meshtools.utils.get_local_mesh(msh,'TRIANGLES');
fprintf('TRIANGLES elements [nme=%d] :\n',size(me,2))
for k=1:size(me,1)
  E=norm(abs(q(:,me(k,:))-msh.POS(L2G(me(k,:)),:)'),Inf);
  fprintf('  Compare the vertex %d of all elements, error=%.5e\n',k,E)
end

n=numel(Stags.LINES);
for i=1:n
  fprintf('LINES elements with tag=%d [nme=%d] :\n',Stags.LINES(i),size(me,2))
  [q,me,L2G]=fc_meshtools.utils.get_local_mesh(msh,'LINES','tags',Stags.LINES(i));
  for k=1:size(me,1)
    E=norm(abs(q(:,me(k,:))-msh.POS(L2G(me(k,:)),:)'),Inf);
    fprintf('  Compare the vertex %d of all elements, error=%.5e\n',k,E)
  end
end
```

```
loading GMSH .m file : <fc-meshtools>/data/condenser110C_small.m
TRIANGLES elements [nme=1467] :
  Compare the vertex 1 of all elements, error=0.00000e+00
  Compare the vertex 2 of all elements, error=0.00000e+00
  Compare the vertex 3 of all elements, error=0.00000e+00
LINES elements with tag=1 [nme=1467] :
  Compare the vertex 1 of all elements, error=0.00000e+00
  Compare the vertex 2 of all elements, error=0.00000e+00
LINES elements with tag=10 [nme=96] :
  Compare the vertex 1 of all elements, error=0.00000e+00
  Compare the vertex 2 of all elements, error=0.00000e+00
LINES elements with tag=21 [nme=15] :
  Compare the vertex 1 of all elements, error=0.00000e+00
  Compare the vertex 2 of all elements, error=0.00000e+00
LINES elements with tag=22 [nme=8] :
  Compare the vertex 1 of all elements, error=0.00000e+00
  Compare the vertex 2 of all elements, error=0.00000e+00
LINES elements with tag=23 [nme=8] :
  Compare the vertex 1 of all elements, error=0.00000e+00
  Compare the vertex 2 of all elements, error=0.00000e+00
LINES elements with tag=24 [nme=8] :
  Compare the vertex 1 of all elements, error=0.00000e+00
  Compare the vertex 2 of all elements, error=0.00000e+00
```

3.7 On simplicial meshes

The followings functions can be used on simplicial meshes (i.e. meshes composed with triangular elements or with tetrahedron elements)

3.7.1 Volumes function

Syntaxe Returns all the element volumes of a mesh given by a dim-by-nq vertices array q and a connectivity array me of dimension (dim+1)-by-nme. One can refer to [1] for computationnal details.

Description

vols=fc_meshtools.simplicial.Volumes(q,me)

vols(k) is the volume of the k-th mesh element where its vertices are the columns of q(:, me(:,k)).

In Listing 11, some examples are provided.

Listing 11: : examples of fc_meshtools.simplicial.Volumes function usage

```
msh2D=fc_meshtools.utils.read_data_m_file('d',2,'dim',2,'box',true);
q2=msh2D.POS';me2=msh2D.TRIANGLES(:,1:3)';
vols2=fc_meshtools.simplicial.Volumes(q2,me2);
fprintf('area=%.16e\n',sum(vols2))
msh3D=fc_meshtools.utils.read_data_m_file('d',3,'dim',3,'box',true);
q3=msh3D.POS';me3=msh3D.TETS(:,1:4)';
vols3=fc_meshtools.simplicial.Volumes(q3,me3);
fprintf('volume=%.16e\n',sum(vols3))
msh3Ds=fc_meshtools.utils.read_data_m_file('d',2,'dim',3,'box',true);
q3Ds=msh3Ds.POS';me3Ds=msh3Ds.TRIANGLES(:,1:3)';
vols3Ds=fc_meshtools.simplicial.Volumes(q3Ds,me3Ds);
fprintf('surface=%.16e\n',sum(vols3Ds))
```

Output

```
loading GMSH .m file : <fc-meshtools>/data/box2D_small.m
area=1.0000000000000000e+00
loading GMSH .m file : <fc-meshtools>/data/box3D_small.m
volume=9.9999999999999967e-01
loading GMSH .m file : <fc-meshtools>/data/box3Ds_small.m
surface=6.0000000000000009e+00
```

3.7.2 Gradient of barycentric coordinates

Syntaxe Returns all the gradients of barycentric coordinates of each element of a mesh given by a dim-by-nq vertices array q and a connectivity array me of dimension (dim+1)-by-nme. One can refer to [1] for computationnal details.

Description

G=fc_meshtools.simplicial.GradBaCo(q,me)

G(k,i,:) is the gradient of the i-th barycentric coordinate of the k-th mesh element.

In Listing 12, some examples are provided.

Listing 12: : examples of fc_meshtools.simplicial.GradBaCo function usage

```
msh2D=fc_meshtools.utils.read_data_m_file('d',2,'dim',2,'box',true);
q2=msh2D.POS';me2=msh2D.TRIANGLES(:,1:3)';
G2=fc_meshtools.simplicial.GradBaCo(q2,me2);
whos('q2','me2','G2')
```

Output

```
loading GMSH .m file : <fc-meshtools>/data/box2D_small.m
  Name       Size            Bytes  Class     Attributes

  G2       180x3x2            8640  double
  me2        3x180            4320  double
  q2         2x107            1712  double
```

3 References

[1] F. Cuvelier. Exact integration for products of power of barycentric coordinates over d-simplexes in R^n. http://hal.archives-ouvertes.fr/hal-00931066v1, June 2018. preprint.

Informations for git maintainers of the fc meshtools Matlab toolbox

git informations on the toolboxes used to build this manual

```
-----------------------------------------------------
   name : fc-meshtools
    tag : 0.2.0
 commit : 3e2d4d43f99de8f8c5f4b69580f4230261bb7dea
   date : 2025-03-31
   time : 11-13-35
 status : 0
-----------------------------------------------------
   name : fc-tools
    tag : 0.1.0
 commit : 8781a7e64952b4f2c3684d97ad4e78ec1cbe2fdc
   date : 2025-03-31
   time : 11-14-20
 status : 0
-----------------------------------------------------
   name : fc-bench
    tag : 0.1.4
 commit : 25e94e40535f90958a7ae9ddcb8fef557487bd9b
   date : 2025-03-28
   time : 12-47-56
 status : 0
-----------------------------------------------------
   name : fc-amat
    tag : 0.1.4
 commit : 63a829130f4412773dbb4a35b6461daa7fc5d40a
   date : 2025-03-28
   time : 12-55-26
 status : 0
-----------------------------------------------------
```

git informations on the LaTeX package used to build this manual

```
-----------------------------------------------------
   name : fctools
    tag :
 commit : 03d38737a795cdbf4e1a8754470e963cdfe83316
   date : 2025-01-24
   time : 09:58:52
 status : 1
-----------------------------------------------------
```

Using the remote configuration repository:

url	ssh://lagagit/MCS/Cuvelier/Matlab/fc-config
commit	43694ef530ee6ca83f9472051ee507ce19bda38d