fc meshtools Octave package, User's Guide*

version 0.1.2

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Abstract

The experimental fc meshtools Octave package contains some simplicial meshes given by their vertices array **q** and connectivity array **me**. Theses meshes can be easily used in other Octave codes for debugging or testing purpose.

0 Contents

*LaTeX manual, revision 0.1.2, compiled with Octave 5.1.0, and packages `fc-meshtools`[0.1.2], `fc-tools`[0.0.29], `fc-bench`[0.1.1], `fc-amat`[0.1.1]

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1 Introduction

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 and stored in the `+fc_meshtools/data` directory. They can be load by using the functions fc_meshtools.simplicial.getMesh2D, fc_meshtools.simplicial.getMesh3D or fc_meshtools.simplicial.getMesh3Ds. Here are the kind of simplicial meshes present in this package:

- 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).

This package was tested on various OS with Octave releases:

	Octave					
Operating system	**4.2.0**	**4.2.1**	**4.2.2**	**4.4.0**	**4.4.1**	**5.1.0**
CentOS 7.6.1810	✓	✓	✓	✓	✓	✓
Debian 9.8	✓	✓	✓	✓	✓	✓
Fedora 29	✓	✓	✓	✓	✓	✓
OpenSUSE Leap 15.0	✓	✓	✓	✓	✓	✓
Ubuntu 18.04.2 LTS	✓	✓	✓	✓	✓	✓
MacOS High Sierra 10.13.6				✓	✓	
MacOS Mojave 10.14				✓	✓	
MacOS Catalina 10.15.2				✓	✓	
Windows 10 (1909)	✓	✓	✓	✓	✓	✓

It is not compatible with Octave releases prior to 4.2.0.

2 Installation

2.1 Installation automatic, all in one (recommanded)

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

ofc_meshtools_install.m

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

For example, to install this package in `~/Octave/packages` directory, one have to copy the file ofc_meshtools_install.m in the `~/Octave/packages` directory. Then in a Octave terminal run the following commands to install the fc meshtools package

```
>> cd ~/Octave/packages
>> ofc_meshtools_install
```

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

```
Parts of the <fc-meshtools> Octave package.
Copyright (C) 2018-2020 F. Cuvelier <cuvelier@math.univ-paris13.fr>

1- Downloading and extracting the packages
2- Setting the <fc-meshtools> package
Write in ~/Octave/packages/fc-meshtools-full/fc_meshtools-0.1.2/
     configure_loc.m ...
3- Using packages :
   ->             fc-tools : 0.0.29
   ->             fc-bench : 0.1.1
   ->              fc-amat : 0.1.1
 with         fc-meshtools : 0.1.2
*** Using instructions
   To use the <fc-meshtools> package:
   addpath('~/Octave/packages/fc-meshtools-full/fc_meshtools-0.1.2')
   fc_meshtools.init()

   See ~/Octave/packages/ofc_meshtools_set.m
```

The complete package (which included the `fc-tools` package) is stored in the directory `~/Octave/packages/fc-meshtools-full` and, for each Octave session, one have to set the package by:

```
>> addpath('~/Octave/packages/fc-meshtools-full/fc-meshtools-0.1.1')
>> 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 ~/Octave/packages/fc-meshtools-full/fc_tools-0.0.29/
     configure_loc.m ...
Try to use default parameters!
 Use fc_bench.configure to configure.
Write in ~/Octave/packages/fc-meshtools-full/fc_bench-0.1.1/configure_loc
     .m ...
Try to use default parameters!
 Use fc_amat.configure to configure.
Write in ~/Octave/packages/fc-meshtools-full/fc_amat-0.1.1/configure_loc.
     m ...
Using fc_meshtools[0.1.2] with fc_tools[0.0.29], fc_bench[0.1.1], fc_amat
     [0.1.1].
```

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

```
Using fc_meshtools[0.1.2] with fc_tools[0.0.29], fc_bench[0.1.1], fc_amat
     [0.1.1].
```

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

`~/Octave/packages/fc-meshtools-full`

3 Simplicial meshes

The functions fc_meshtools.simplicial.getMesh2D, gfc_meshtools.simplicial.etMesh3D and fc_meshtools.simplicial.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 $0 \leqslant d \leqslant dim$ 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_meshtools.simplicial.getMesh3D(3) return a 3-simplicial mesh (main mesh) in space dimension $dim = 3$,
- [q2,me2,toGlobal2]=fc_meshtools.simplicial.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 Functions

4.1 getMesh functions

Returns a vertices array q, a connectivity array me and an indices array toGlobal.

Description

[q,me,toGlobal]=fc_meshtools.simplicial.getMesh3D(d)

[q,me,toGlobal]=fc_meshtools.simplicial.getMesh3Ds(d)

[q,me,toGlobal]=fc_meshtools.simplicial.getMesh2D(d)

Returns a vertices array q, a connectivity array me and an indices array toGlobal depending on the value of the d. For a 3D mesh, $d \in [\![0,3]\!]$, and for a 2D or 3Ds mesh, $d \in [\![0,2]\!]$.

In Listing 2, some examples are provided.

Listing 1: : examples of fc_meshtools.simplicial.getMesh3D function usage

```
[q2,me2,toG2]=fc_meshtools.simplicial.getMesh3D(2);
[q3,me3,toG3]=fc_meshtools.simplicial.getMesh3D(3);
whos('q2','me2','toG2','q3','me3','toG3')
fprintf('Error: %.5e\n',norm(q3(:,toG2) - q2,Inf))
```

Output

```
Variables in the current scope:

  Attr Name      Size                Bytes  Class
  ==== ====      ====                =====  =====
       q2        3x7533             180792  double
       me2       3x15074            361776  double
       toG2      1x7533              60264  double
       q3        3x17416            417984  double
       me3       4x84302           2697664  double
       toG3      1x17416            139328  double

Total is 482226 elements using 3857808 bytes

Error: 0.00000e+00
```

4.2 Volumes function

Syntaxe Returns all the element volumes of a mesh given by a vertices array q and a connectivity array me. 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 2, some examples are provided.

Listing 2: : examples of fc_meshtools.simplicial.Volumes function usage

```
[q,me,toG]=fc_meshtools.simplicial.getMesh3D(2);
vols=fc_meshtools.simplicial.Volumes(q,me);
whos('q','me','toG','vols')
```

Output

```
Variables in the current scope:

  Attr Name      Size                Bytes  Class
  ==== ====      ====                =====  =====
       q         3x7533             180792  double
       me        3x15074            361776  double
       toG       1x7533              60264  double
       vols      1x15074            120592  double

Total is 90428 elements using 723424 bytes
```

4.3 Gradient of barycentric coordinates

Syntaxe Returns all the gradients of barycentric coordinates of each element of a mesh given by a vertices array q and a connectivity array me. 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 3, some examples are provided.

Listing 3: : examples of fc_meshtools.simplicial.GradBaCo function usage

```
[q,me,toG]=fc_meshtools.simplicial.getMesh3D(3);
G=fc_meshtools.simplicial.GradBaCo(q,me);
whos('q','me','toG','G')
```

Output

```
Variables in the current scope:

  Attr Name       Size                    Bytes  Class
  ==== ====       ====                    =====  =====
       q          3x17416                417984  double
       me         4x84302               2697664  double
       toG        1x17416                139328  double
       G      84302x4x3                8092992  double

Total is 1418496 elements using 11347968 bytes
```

4 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.