Numerical software 2
ANGENER

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Lecture 2

Code ANGENER

It modifies the input mesh $\mathscr{T}_h$ and creates $\mathscr{T}_h^{\rm NEW}$

Two versions

```
msekce.karlin.mff.cuni.cz/˜dolejsi/angen/angen3.0.htm
msekce.karlin.mff.cuni.cz/˜dolejsi/angen/angen3.1.htm
```

Downloading

```
gunzip angener3.1.tar.gz
tar xf angener3.1.tar
```

Instalation

```
make
```

Running (after preparation of data files)

```
./side
```

Files (1)

`main.f`	source file
`solver.f`	source file
`rest.f`	source file
`moving.f`	source file
`swapping.f`	source file
`insert.f`	source file
`remove.f`	source file
`rembou.f`	source file
`work.inc`	included file of array declaration
`makefile`	makefile used for translation

- `work.inc` declare the amount of allocated memory
- Error in function MEMO: 10200 values miss in blank common

  $\Longrightarrow$ not enough of memory
- increase dimension of array `work` in `work.inc`
- `rm -f main.o` & `make`

Files (2)

`paramet`	sample of input file
`profiles.01`	sample of input file – $\Omega = [0, 1] \times [0, 1]$
`triang.01`	sample of input file – $\Omega = [0, 1] \times [0, 1]$
`profiles.gam`	sample of input file – GAMM channel
`triang.gam`	sample of input file – GAMM channel
`profiles.2na`	sample of input file – double NACA profile
`triang.2na`	sample of input file – double NACA profile
`profiles.dca`	sample of input file – periodic DCA08 profile
`triang.dca`	sample of input file – periodic DCA08 profile
`spline.f`	first source code for spline interpolation
`library.f`	library subroutine for spline code
`readme`	first instruction
`manual.ps`	description of ANGENER code

Basic description (1)

Modes of ANGENER

- uniform mesh
- adapted mesh

Uniform mesh

Input files:

- `paramet` - contains the parameters for AMA algorithm,
- `profiles` - contains the description of curved parts of $\partial\Omega$,
- `triang` - input triangulation $\mathscr{T}_h$,

Output files:

- `triangx` - new triangulation $\mathscr{T}_h^{\mathrm{NEW}}$,
- `mesh` - figure of $\mathscr{T}_h^{\mathrm{NEW}}$ for direct use in `gnuplot`.

Basic description (2)

Adapted mesh

Input files:

- `paramet` - contains the parameters for AMA algorithm,
- `profiles` - contains the description of curved parts of $\partial\Omega$,
- `triang` - input triangulation $\mathscr{T}_h$,
- `results` - results u_h computed on $\mathscr{T}_h$.

Output files:

- `triangx` - new triangulation $\mathscr{T}_h^{\mathrm{NEW}}$,
- `resultsx` - results u_h interpolated on $\mathscr{T}_h^{\mathrm{NEW}}$,
- `mesh` - figure of $\mathscr{T}_h^{\mathrm{NEW}}$ for direct use in `gnuplot`.

Important variables and arrays in ANGENER

$nelem$		# of triangles of $\mathscr{T}_h$
$npoin$		# of nodes (vertices) of $\mathscr{T}_h$
$nbelm$		# of boundary segments of $\mathscr{T}_h$
nbc		# of boundary components
nbp		# of non-polygonal parts of $\partial\Omega$
$ndim$		# of components of solution (=1 for scalar equation)
$x(i)$	$i = 1, \dots, npoin$	$x-$coordinates of nodes of $\mathscr{T}_h$
$y(i)$	$i = 1, \dots, npoin$	$y-$coordinates of nodes of $\mathscr{T}_h$
$lnd(i,j)$	$i = 1, \dots, nelem, \ j = 1, 2, 3$	nodes of triangles
$lbn(i,j)$	$i = 1, \dots, nbelm, \ j = 1, 2$	nodes of boundary edge
$ibc(i)$	$i = 1, \dots, nbelm$	type of BC for boundary edges

File paramet

ityp	type of construction, $0 \le ityp \le ndim$
ndim	number of component of seeking solution
ifv	type of mesh association
pos	positivity
numel	prescribed number of elements for uniform triangulation
$eps1$	ε_1
p	p

- $ityp = 0$: a uniform triangulation is constructed
- $ityp > 0$: an adapted triangulation is constructed using $ityp -$ th component of u (it has *ndim* components)
- $ifv = 0$: a cell-vertex scheme (continuous P_1)
- $ifv = 1$: a cell-centered scheme (discontinuous P_0)
- $pos > 0$: control the shape regularity

File `paramet` – example

```
0          ityp ( 0 - uniform trian, >0 - component of solution)
1          ndim
0          ifv ( 0 -cell vertex, 1- cell centered)
0.02       pos (=positivity)
500        numel (= c)
1.E+10     epsilon1
1.         p
```

File `profile`

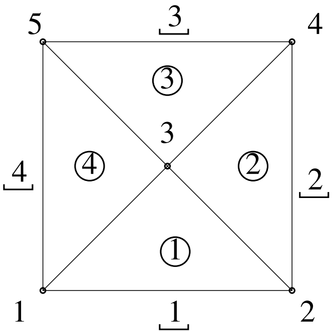
a dense list of nodes defining nonpolygonal boundary:

```
2
16085
1. 0.249999985
0.999875009 0.249982268
0.999750018 0.249964535
⋮
0.999750018 0.250035465
0.999875009 0.250017732
1. 0.25
801
0.000 1.25
-0.00490878057 1.24999034
-0.00981743075 1.2499615
⋮
-0.0147257112 -1.24991322
-0.00981721189 -1.2499615
-0.00490856264 -1.24999034
0.000 -1.25
```

Files triang and triangx: unit square

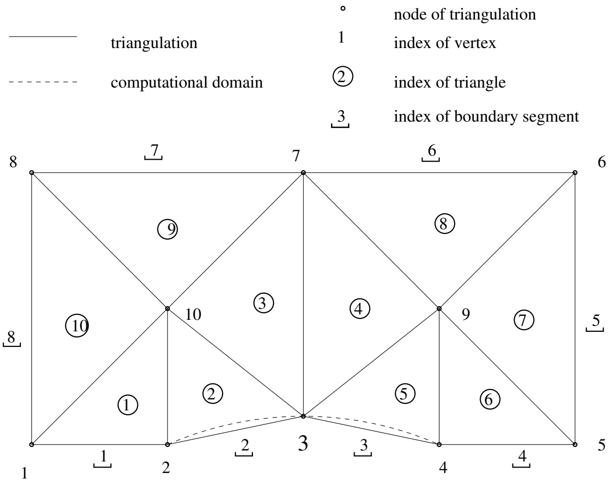
```
5 4 4          npoin nelem nbelm
0.0 0.0 0 0    periodic boundary
0.0 0.0        x(1) y(1)
1.0 0.0
0.5 0.5
1.0 1.0
0.0 1.0        x(5) y(5)
1 2 3          Ind(1,1) Ind(1,2) Ind(1,3)
2 4 3
4 5 3
5 1 3          Ind(4,1) Ind(4,2) Ind(4,3)
1 2 1          Ibn(1,1) Ibn(1,2) ibc(1)
2 4 2
4 5 3
5 1 4          Ibn(4,1) Ibn(4,2) ibc(4)
```

∘	node of triangulation
1	index of vertex
②	index of triangle
$\underline{3}$	index of boundary segn



Files triang and triangx: GAMM channel

```
10 10 8 4
0. 0. 0 0
-1.0 0.0
-0.5 0.0
0.0 0.1
0.5 0.0
1.0 0.0
1.0 1.0
0.0 1.0
-1.0 1.0
0.5 0.5
-0.5 0.5
1 2 10
2 3 10
3 7 10
3 9 7
3 4 9
4 5 9
5 6 9
6 7 9
7 8 10
8 1 10
1 2 3
2 3 3
3 4 3
4 5 3
5 6 2
6 7 4
7 8 4
8 1 1
```



Files `result` and `resultsx`

$ifv = 0$: cell-vertex, piecewise linear

$$\begin{array}{llll}
w(1,1) & w(1,2) & \dots & w(1,ndim) \\
w(2,1) & w(2,2) & \dots & w(1,ndim) \\
w(3,1) & w(3,2) & \dots & w(3,ndim) \\
\vdots & \vdots & & \vdots \\
w(npoin,1) & w(npoin,2) & \dots & w(npoin,ndim)
\end{array}$$

$ifv = 1$: cell-centered, piecewise constant

$$\begin{array}{llll}
w(1,1) & w(1,2) & \dots & w(1,ndim) \\
w(2,1) & w(2,2) & \dots & w(1,ndim) \\
w(3,1) & w(3,2) & \dots & w(3,ndim) \\
\vdots & \vdots & & \vdots \\
w(nelem,1) & w(nelem,2) & \dots & w(nelem,ndim)
\end{array}$$

Example of performing the code

Unit square

```
cp triang.01 triang
cp profiles.01 profiles
./side
gnuplot> p ’mesh’ w l
```

GAMM channel

```
cp triang.gam triang
cp profiles.gam profiles
./side
gnuplot> p ’mesh’ w l
```

Main task 3

Solve numerically the following PDE:

$$\begin{aligned} -\Delta u &= 90x_1^8(1-x_2^{20}) + 380x_2^{18}(1-x_1^{10}), \qquad \text{in } \Omega = (0,1)^2, \quad (1) \\ u &= u_D \quad \text{on } \partial\Omega, \end{aligned}$$

where u_D is the exact solution given by

$$u(x_1,x_2) = (1-x_1^{10})(1-x_2^{20}), \quad (x_1,x_2) \in \Omega.$$

Instructions

1. Solve problem (1) by a suitable numerical method and by an arbitrary code based on your choice. You can used freely available software or you can write a simple own code.
2. Carry out several adaptation cycles using ANGENER.
3. Use a suitable visualization of the results, namely the adapted grids.

Hint: Possible solution

Combination of codes

- FEM code from Tutorials 11 (sparse) `femP1`
- ANGENER

Comments

- the same structure of files `triang`
- (1) is already implemented in `femP1`
- output of `femP1` in the ANGENER's format `results` is already available
- output of ANGENER: `resultsx` can be used for `femP1` (not necessary)
- careful setting of `paramet` file: *ityp*, *ifv*

Main task 4

Solve numerically the following PDE:

$$\begin{aligned} -\Delta u &= 0 \quad \text{in}\Omega := (-1,1)\times(-1,1)\setminus[0,1], \\ u &= u_D \quad \text{on } \partial\Omega, \end{aligned} \tag{2}$$

where u_D is the exact solution given by

$$u(r,\phi) = r^{2/3}\sin(2\phi/3), \quad (r,\phi)\in\Omega \text{ are polar coordinates.}$$

Instructions

1. Using ANGENER, generate a sequence of quasi-uniform grids of Ω and set experimental order of convergence (EOC).
2. Using the code ANGENER in combination with FEM generate a sequence of adaptively refined grids and set EOC.
3. Use a suitable visualization of the adapted grids and the corresponding solutions.