

NAG Toolbox for MATLAB

d06ca

1 Purpose

d06ca uses a barycentering technique to smooth a given mesh.

2 Syntax

```
[coor, ifail] = d06ca(coor, edge, conn, numfix, itrace, nqint, 'nv', nv,
    'nelt', nelt, 'nedge', nedge, 'nvfix', nvfix)
```

3 Description

d06ca uses a barycentering approach to improve the smoothness of a given mesh. The measure of quality used for a triangle K is

$$Q_K = \alpha \frac{h_K}{\rho_K};$$

where h_K is the diameter (length of the longest edge) of K , ρ_K is the radius of its inscribed circle and $\alpha = \frac{\sqrt{3}}{6}$ is a normalization factor chosen to give $Q_K = 1$ for an equilateral triangle. Q_K ranges from 1, for an equilateral triangle, to ∞ , for a totally flat triangle.

d06ca makes small perturbation to vertices (using a barycenter formula) in order to give a reasonably good value of Q_K for all neighbouring triangles. Some vertices may optionally be excluded from this process.

For more details about the smoothing method, especially with regard to differing quality, consult the D06 Chapter Introduction as well as George and Borouchaki 1998.

This function is derived from material in the MODULEF package from INRIA (Institut National de Recherche en Informatique et Automatique).

4 References

George P L and Borouchaki H 1998 *Delaunay Triangulation and Meshing: Application to Finite Elements* Editions HERMES, Paris

5 Parameters

5.1 Compulsory Input Parameters

1: **coor(2,nv)** – double array

coor(1, i) contains the x co-ordinate of the i th input mesh vertex, for $i = 1, \dots, \mathbf{nv}$; while **coor**(2, i) contains the corresponding y co-ordinate.

2: **edge(3,nedge)** – int32 array

The specification of the boundary or interface edges. **edge**(1, j) and **edge**(2, j) contain the vertex numbers of the two end points of the j th boundary edge. **edge**(3, j) is a user-supplied tag for the j th boundary or interface edge: **edge**(3, j) = 0 for an interior edge and has a nonzero tag otherwise.

Constraint: $1 \leq \mathbf{edge}(i, j) \leq \mathbf{nv}$ and $\mathbf{edge}(1, j) \neq \mathbf{edge}(2, j)$, for $i = 1, 2$ and $j = 1, 2, \dots, \mathbf{nedge}$.

3: **conn(3,nelt) – int32 array**

The connectivity of the mesh between triangles and vertices. For each triangle j , **conn**(i,j) gives the indices of its three vertices (in anticlockwise order), for $i = 1, 2, 3$ and $j = 1, \dots, \mathbf{nelt}$.

Constraint: $1 \leq \mathbf{conn}(i,j) \leq \mathbf{nv}$ and $\mathbf{conn}(1,j) \neq \mathbf{conn}(2,j)$ and $\mathbf{conn}(1,j) \neq \mathbf{conn}(3,j)$ and $\mathbf{conn}(2,j) \neq \mathbf{conn}(3,j)$, for $i = 1, 2, 3$ and $j = 1, 2, \dots, \mathbf{nelt}$.

4: **numfix(*) – int32 array**

Note: the dimension of the array **numfix** must be at least $\max(1, \mathbf{nvfix})$.

The indices in **coor** of fixed interior vertices of the input mesh.

Constraint: if $\mathbf{nvfix} > 0$, $1 \leq \mathbf{numfix}(i) \leq \mathbf{nv}$, for $i = 1, 2, \dots, \mathbf{nvfix}$.

5: **itrace – int32 scalar**

The level of trace information required from d06ca.

itrace ≤ 0

No output is generated.

itrace = 1

A histogram of the triangular element qualities is printed on the current advisory message unit (see x04ab) before and after smoothing. This histogram gives the lowest and the highest triangle quality as well as the number of elements lying in each of the **nqint** equal intervals between the extremes.

itrace > 1

The output is similar to that produced when **itrace** = 1 but the connectivity between vertices and triangles (for each vertex, the list of triangles in which it appears) is given.

You are advised to set **itrace** = 0, unless you are experienced with finite element meshes.

6: **nqint – int32 scalar**

The number of intervals between the extreme quality values for the input and the smoothed mesh.

If **itrace** = 0, **nqint** is not referenced.

5.2 Optional Input Parameters

1: **nv – int32 scalar**

Default: The dimension of the array **coor**.

the total number of vertices in the input mesh.

Constraint: $\mathbf{nv} \geq 3$.

2: **nelt – int32 scalar**

Default: The dimension of the array **conn**.

the number of triangles in the input mesh.

Constraint: $\mathbf{nelt} \leq 2 \times \mathbf{nv} - 1$.

3: **nedge – int32 scalar**

Default: The dimension of the array **edge**.

the number of the boundary and interface edges in the input mesh.

Constraint: $\mathbf{nedge} \geq 1$.

4: **nvfix – int32 scalar**

Default: The dimension of the array **numfix**.

The number of fixed vertices in the input mesh.

Constraint: $0 \leq \mathbf{nvfix} \leq \mathbf{nv}$.

5.3 Input Parameters Omitted from the MATLAB Interface

iwork, liwork, rwork, lrwork

5.4 Output Parameters1: **coor(2,nv) – double array**

coor(1,*i*) will contain the *x* co-ordinate of the *i*th smoothed mesh vertex, for $i = 1, \dots, \mathbf{nv}$; while **coor**(2,*i*) will contain the corresponding *y* co-ordinate. Note that the co-ordinates of boundary and interface edge vertices, as well as those specified by you (see the description of **numfix**), are unchanged by the process.

2: **ifail – int32 scalar**

0 unless the function detects an error (see Section 6).

6 Error Indicators and Warnings

Errors or warnings detected by the function:

ifail = 1

On entry, **nv** < 3,
 or **nelt** > $2 \times \mathbf{nv} - 1$,
 or **nedge** < 1,
 or **edge**(*i,j*) < 1 or **edge**(*i,j*) > **nv** for some $i = 1, 2$ and $j = 1, \dots, \mathbf{nedge}$,
 or **edge**(1,*j*) = **edge**(2,*j*) for some $j = 1, \dots, \mathbf{nedge}$,
 or **conn**(*i,j*) < 1 or **conn**(*i,j*) > **nv** for some $i = 1, 2, 3$ and $j = 1, \dots, \mathbf{nelt}$,
 or **conn**(1,*j*) = **conn**(2,*j*) or **conn**(1,*j*) = **conn**(3,*j*) or **conn**(2,*j*) = **conn**(3,*j*) for some $j = 1, \dots, \mathbf{nelt}$,
 or **nvfix** < 0 or **nvfix** > **nv**,
 or **numfix**(*i*) < 1 or **numfix**(*i*) > **nv** for some $i = 1, \dots, \mathbf{nvfix}$ if **nvfix** > 0,
 or **liwork** < $8 \times \mathbf{nelt} + 2 \times \mathbf{nv}$,
 or **lrwork** < $2 \times \mathbf{nv} + \mathbf{nelt}$.

ifail = 2

A serious error has occurred in an internal call to an auxiliary function. Check the input mesh, especially the connectivity between triangles and vertices (the parameter **conn**). Setting **itrace** > 1 may provide more information. If the problem persists, contact NAG.

7 Accuracy

Not applicable.

8 Further Comments

Not applicable.

9 Example

```

coor = zeros(2, 400);
coor(1, 2) = 0.05263157894736842;
coor(1, 3) = 0.1052631578947368;
coor(1, 4) = 0.1578947368421053;
coor(1, 5) = 0.2105263157894737;
coor(1, 6) = 0.2631578947368421;
coor(1, 7) = 0.3157894736842105;
coor(1, 8) = 0.3684210526315789;
coor(1, 9) = 0.4210526315789473;
coor(1, 10) = 0.4736842105263158;
coor(1, 11) = 0.5263157894736842;
coor(1, 12) = 0.5789473684210527;
coor(1, 13) = 0.631578947368421;
coor(1, 14) = 0.6842105263157894;
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coor(1, 17) = 0.8421052631578947;
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coor(1, 19) = 0.9473684210526315;
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coor(1, 22) = 0.04257113699483006;
coor(1, 23) = 0.1075338803246166;
coor(1, 24) = 0.1717984614336813;
coor(1, 25) = 0.2103928201071081;
coor(1, 26) = 0.2495520733792397;
coor(1, 27) = 0.2961006824646039;
coor(1, 28) = 0.3575620100039046;
coor(1, 29) = 0.4205288219545923;
coor(1, 30) = 0.4637329505439333;
coor(1, 31) = 0.5140696487172095;
coor(1, 32) = 0.6010505891764107;
coor(1, 33) = 0.6159971427264105;
coor(1, 34) = 0.6781910301437432;
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coor(1, 36) = 0.7765988725044779;
coor(1, 37) = 0.8395375474615249;
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coor(1, 48) = 0.3857740425374745;
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coor(1, 53) = 0.641420995435965;
coor(1, 54) = 0.6970903365302695;
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coor(1, 56) = 0.8004665386968891;
coor(1, 57) = 0.8425496366921083;
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coor(1, 291) = 0.5152771629811512;  
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conn(3, 718) = 397;
conn(3, 719) = 399;
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conn(3, 721) = 400;
conn(3, 722) = 399;
numfix = zeros(0,0,'int32');
itrace = int32(1);
ngint = int32(10);
[coorOut, ifail] = d06ca(coor, edge, conn, numfix, itrace, ngint)

```

```

coorOut =
    array elided
ifail =
    0

```

BEFORE SMOOTHING

MINIMUM SMOOTHNESS MEASURE: 1.0048907

MINIMUM SMOOTHNESS MEASURE: 133.2110681

DISTRIBUTION

INTERVAL	NUMBER OF ELEMENTS
1.0048907 - 14.2255084	720
14.2255084 - 27.4461262	0
27.4461262 - 40.6667439	0
40.6667439 - 53.8873616	0
53.8873616 - 67.1079794	0
67.1079794 - 80.3285971	0
80.3285971 - 93.5492149	0
93.5492149 - 106.7698326	0
106.7698326 - 119.9904504	0
119.9904504 - 133.2110681	1

AFTER SMOOTHING

MINIMUM SMOOTHNESS MEASURE: 1.3346259

MINIMUM SMOOTHNESS MEASURE: 1.4572261

DISTRIBUTION

INTERVAL	NUMBER OF ELEMENTS
1.3346259 - 1.3468859	10
1.3468859 - 1.3591459	36
1.3591459 - 1.3714060	46
1.3714060 - 1.3836660	117
1.3836660 - 1.3959260	186
1.3959260 - 1.4081860	137
1.4081860 - 1.4204460	106
1.4204460 - 1.4327061	51
1.4327061 - 1.4449661	28
1.4449661 - 1.4572261	4