NAG Library Function Document

nag_mesh2d_bound (d06bac)

1 Purpose

nag_mesh2d_bound (d06bac) generates a boundary mesh on a closed connected subdomain Ω of $\mathbb{R}^2$.

2 Specification

```
#include <nag.h>
#include <nagd06.h>
```

```
void nag_mesh2d_bound (Integer nlines, const double coorch[],
     const Integer lined[],
     double (*fbnd)(Integer i, double x, double y, Nag_Comm *comm),
     const double crus[], Integer sdcrus, const double rate[], Integer ncomp,
     const Integer nlcomp[], const Integer lcomp[], Integer nvmax,
     Integer nedmx, Integer *nvb, double coor[], Integer *nedge,
     Integer edge[], Integer itrace, const char *outfile, Nag_Comm *comm,
     NagError *fail)
```

3 Description

Given a closed connected subdomain Ω of $\mathbb{R}^2$, whose boundary $\partial\Omega$ is divided by characteristic points into m distinct line segments, nag_mesh2d_bound (d06bac) generates a boundary mesh on $\partial\Omega$. Each line segment may be a straight line, a curve defined by the equation $f(x,y) = 0$, or a polygonal curve defined by a set of given boundary mesh points.

This function is primarily designed for use with either nag_mesh2d_inc (d06aac) (a simple incremental method) or nag_mesh2d_delaunay (d06abc) (Delaunay–Voronoi method) or nag_mesh2d_front (d06acc) (Advancing Front method) to triangulate the interior of the domain Ω. For more details about the boundary and interior mesh generation, 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 Arguments

1: **nlines** – Integer *Input*

On entry: m, the number of lines that define the boundary of the closed connected subdomain (this equals the number of characteristic points which separate the entire boundary $\partial\Omega$ into lines).

Constraint: **nlines** ≥ 1.

2: **coorch**[**2** $\times$ **nlines**] – const double *Input*

Note: the (i,j)th element of the matrix is stored in **coorch**$[(j-1) \times 2 + i - 1]$.

On entry: **coorch**$[(i-1) \times 2]$ contains the x coordinate of the ith characteristic point, for $i = 1, 2, \ldots,$ **nlines**; while **coorch**$[(i-1) \times 2 + 1]$ contains the corresponding y coordinate.

3: **lined**[**4** × **nlines**] – const Integer *Input*

Note: the (i,j)th element of the matrix is stored in **lined**$[(j-1)\times 4+i-1]$.

On entry: the description of the lines that define the boundary domain. The line i, for $i=1,2,\ldots,m$, is defined as follows:

lined$[(i-1)\times 4]$
The number of points on the line, including two end points.

lined$[(i-1)\times 4+1]$
The first end point of the line. If **lined**$[(i-1)\times 4+1]=j$, then the coordinates of the first end point are those stored in **coorch**$[(j-1)\times 2]$, **coorch**$[(j-1)\times 2+1]$.

lined$[(i-1)\times 4+2]$
The second end point of the line. If **lined**$[(i-1)\times 4+2]=k$, then the coordinates of the second end point are those stored in **coorch**$[(k-1)\times 2]$, **coorch**$[(k-1)\times 2+1]$.

lined$[(i-1)\times 4+3]$
This defines the type of line segment connecting the end points. Additional information is conveyed by the numerical value of **lined**$[(i-1)\times 4+3]$ as follows:

(i) **lined**$[(i-1)\times 4+3]>0$, the line is described in **fbnd** with **lined**$[(i-1)\times 4+3]$ as the index. In this case, the line must be described in the trigonometric (anticlockwise) direction;

(ii) **lined**$[(i-1)\times 4+3]=0$, the line is a straight line;

(iii) if **lined**$[(i-1)\times 4+3]<0$, say (i.e., **lined**$[(i-1)\times 4+3]=-p$ for some index p), then the line is a polygonal arc joining the end points and interior points specified in **crus**. In this case the line contains the points whose coordinates are stored in
coorch$[(j-1)\times 2+z]$,
crus$[(p-1)\times 2+z]$,
crus$[p\times 2+z],\ldots,$ **crus**$[(p+r-4)\times 2+z]$,
coorch$[(k-1)\times 2+z]$,
where $z\in\{0,1\}$, $r=$ **lined**$[(i-1)\times 4]$, $j=$ **lined**$[(i-1)\times 4+1]$ and $k=$ **lined**$[(i-1)\times 4+2]$.

Constraints:

$2\leq$ **lined**$[(i-1)\times 4]$;
$1\leq$ **lined**$[(i-1)\times 4+1]\leq$ **nlines**;
$1\leq$ **lined**$[(i-1)\times 4+2]\leq$ **nlines**;
lined$[(i-1)\times 4+1]\neq$ **lined**$[(i-1)\times 4+2]$, for $i=1,2,\ldots,$ **nlines**.

For each line described by **fbnd** (lines with **lined**$[(i-1)\times 4+3]>0$, for $i=1,2,\ldots,$ **nlines**) the two end points (**lined**$[(i-1)\times 4+1]$ and **lined**$[(i-1)\times 4+2]$) lie on the curve defined by index **lined**$[(i-1)\times 4+3]$ in **fbnd**, i.e.,

fbnd(**lined**$[(i-1)\times 4+3]$, **coorch**$[($**lined**$[(i-1)\times 4+1]-1)\times 2]$,
coorch$[($**lined**$[(i-1)\times 4+1]-1)\times 2+1]$, **comm**$)=0$;

fbnd(**lined**$[(i-1)\times 4+3]$, **coorch**$[($**lined**$[(i-1)\times 4+2]-1)\times 2]$,
coorch$[($**lined**$[(i-1)\times 4+2]-1)\times 2+1]$, **comm**$)=0$, for $i=1,2,\ldots,$ **nlines**.

For all lines described as polygonal arcs (lines with **lined**$[(i-1)\times 4+3]<0$, for $i=1,2,\ldots,$ **nlines**) the sets of intermediate points (i.e., $[-$**lined**$[(i-1)\times 4+3]:-$**lined**$[(i-1)\times 4+3]+$**lined**$[(i-1)\times 4]-3]$ for all i such that **lined**$[(i-1)\times 4+3]<0$) are not overlapping. This can be expressed as:

$$-\textbf{lined}[(i-1)\times 4+3]+\textbf{lined}[(i-1)\times 4]-3=\sum_{\{i,\textbf{lined}[(i-1)\times 4+3]<0\}}\{\textbf{lined}[(i-1)\times 4]-2\}$$

or

$$-\textbf{lined}[(i-1)\times 4+3]+\textbf{lined}[(i-1)\times 4]-2=-\textbf{lined}[(j-1)\times 4+3],$$

for a j such that $j=1,2,\ldots,$ **nlines**, $j\neq i$ and **lined**$[(j-1)\times 4+3]<0$.

4: **fbnd** – function, supplied by the user *External Function*

fbnd must be supplied to calculate the value of the function which describes the curve $\{(x, y) \in \mathbb{R}^2;\ \text{such that}\ f(x, y) = 0\}$ on segments of the boundary for which **lined**$[(i-1) \times 4 + 3] > 0$. If there are no boundaries for which **lined**$[(i-1) \times 4 + 3] > 0$ **fbnd** will never be referenced by nag_mesh2d_bound (d06bac), in which case **fbnd** may be **NULLFN**.

The specification of **fbnd** is:

```
double fbnd (Integer i, double x, double y, Nag_Comm *comm)
```

1: **i** – Integer *Input*

On entry: **lined**$[3][i-1]$, the reference index of the line (portion of the contour) i described.

2: **x** – double *Input*

3: **y** – double *Input*

On entry: the values of x and y at which $f(x, y)$ is to be evaluated.

4: **comm** – Nag_Comm *

Pointer to structure of type Nag_Comm; the following members are relevant to **fbnd**.

user – double *
iuser – Integer *
p – Pointer

The type Pointer will be `void *`. Before calling nag_mesh2d_bound (d06bac) you may allocate memory and initialize these pointers with various quantities for use by **fbnd** when called from nag_mesh2d_bound (d06bac) (see Section 3.2.1.1 in the Essential Introduction).

5: **crus**$[2 \times$ **sdcrus**$]$ – const double *Input*

Note: the (i, j)th element of the matrix is stored in **crus**$[(j-1) \times 2 + i - 1]$.

On entry: the coordinates of the intermediate points for polygonal arc lines. For a line i defined as a polygonal arc (i.e., **lined**$[(i-1) \times 4 + 3] < 0$), if $p = -$**lined**$[(i-1) \times 4 + 3]$, then **crus**$[(k-1) \times 2]$, for $k = p, \ldots, p +$ **lined**$[(i-1) \times 4] - 3$, must contain the x coordinate of the consecutive intermediate points for this line. Similarly **crus**$[(k-1) \times 2 + 1]$, for $k = p, \ldots, p +$ **lined**$[(i-1) \times 4] - 3$, must contain the corresponding y coordinate.

6: **sdcrus** – Integer *Input*

On entry: the half dimension of the array **crus** as declared in the function from which nag_mesh2d_bound (d06bac) is called.

Constraint: **sdcrus** $\geq \sum_{\{i, \mathbf{lined}[(i-1) \times 4 + 3] < 0\}} \{\mathbf{lined}[(i-1) \times 4] - 2\}$.

7: **rate**$[$**nlines**$]$ – const double *Input*

On entry: **rate**$[i-1]$ is the geometric progression ratio between the points to be generated on the line i, for $i = 1, 2, \ldots, m$ and **lined**$[(i-1) \times 4 + 3] \geq 0$.

If **lined**$[(i-1) \times 4 + 3] < 0$, **rate**$[i-1]$ is not referenced.

Constraint: if **lined**$[(i-1) \times 4 + 3] \geq 0$, **rate**$[i-1] > 0.0$, for $i = 1, 2, \ldots,$ **nlines**.

8: **ncomp** – Integer *Input*

On entry: n, the number of separately connected components of the boundary.

Constraint: **ncomp** ≥ 1.

9: **nlcomp**[**ncomp**] – const Integer *Input*

On entry: $|$**nlcomp**$[k-1]|$ is the number of line segments in component k of the contour. The line i of component k runs in the direction **lined**$[(i-1) \times 4 + 1]$ to **lined**$[(i-1) \times 4 + 2]$ if **nlcomp**$[k-1] > 0$, and in the opposite direction otherwise; for $k = 1, 2, \ldots, n$.

Constraints:

$1 \leq |$**nlcomp**$[k-1]| \leq$ **nlines**, for $k = 1, 2, \ldots,$ **ncomp**;

$\sum_{k=1}^{n} |$**nlcomp**$[k-1]| =$ **nlines**.

10: **lcomp**[**nlines**] – const Integer *Input*

On entry: **lcomp** must contain the list of line numbers for the each component of the boundary. Specifically, the line numbers for the kth component of the boundary, for $k = 1, 2, \ldots,$ **ncomp**, must be in elements $l1 - 1$ to $l2 - 1$ of **lcomp**, where $l2 = \sum_{i=1}^{k} |$**nlcomp**$[i-1]|$ and $l1 = l2 + 1 - |$**nlcomp**$[k-1]|$.

Constraint: **lcomp** must hold a valid permutation of the integers $[1,$ **nlines**$]$.

11: **nvmax** – Integer *Input*

On entry: the maximum number of the boundary mesh vertices to be generated.

Constraint: **nvmax** $\geq$ **nlines**.

12: **nedmx** – Integer *Input*

On entry: the maximum number of boundary edges in the boundary mesh to be generated.

Constraint: **nedmx** ≥ 1.

13: **nvb** – Integer * *Output*

On exit: the total number of boundary mesh vertices generated.

14: **coor**[**2** × **nvmax**] – double *Output*

Note: the (i, j)th element of the matrix is stored in **coor**$[(j-1) \times 2 + i - 1]$.

On exit: **coor**$[(i-1) \times 2]$ will contain the x coordinate of the ith boundary mesh vertex generated, for $i = 1, 2, \ldots,$ **nvb**; while **coor**$[(i-1) \times 2 + 1]$ will contain the corresponding y coordinate.

15: **nedge** – Integer * *Output*

On exit: the total number of boundary edges in the boundary mesh.

16: **edge**[**3** × **nedmx**] – Integer *Output*

Note: the (i, j)th element of the matrix is stored in **edge**$[(j-1) \times 3 + i - 1]$.

On exit: the specification of the boundary edges. **edge**$[(j-1) \times 3]$ and **edge**$[(j-1) \times 3 + 1]$ will contain the vertex numbers of the two end points of the jth boundary edge. **edge**$[(j-1) \times 3 + 2]$ is a reference number for the jth boundary edge and

edge$[(j-1) \times 3+2]$ = **lined**$[(i-1) \times 4+3]$, where i and j are such that the jth edges is part of the ith line of the boundary and **lined**$[(i-1) \times 4+3] \geq 0$;

edge$[(j-1) \times 3+2] = 100 + |$**lined**$[(i-1) \times 4+3]|$, where i and j are such that the jth edges is part of the ith line of the boundary and **lined**$[(i-1) \times 4+3] < 0$.

Note that the edge vertices are numbered from 1 to **nvb**.

17: **itrace** – Integer *Input*

On entry: the level of trace information required from nag_mesh2d_bound (d06bac).

itrace $= 0$ or **itrace** < -1
No output is generated.

itrace $= 1$
Output from the boundary mesh generator is printed. This output contains the input information of each line and each connected component of the boundary.

itrace $= -1$
An analysis of the output boundary mesh is printed on the current advisory message unit. This analysis includes the orientation (clockwise or anticlockwise) of each connected component of the boundary. This information could be of interest to you, especially if an interior meshing is carried out using the output of this function, calling either nag_mesh2d_inc (d06aac), nag_mesh2d_delaunay (d06abc) or nag_mesh2d_front (d06acc).

itrace > 1
The output is similar to that produced when **itrace** $= 1$, but the coordinates of the generated vertices on the boundary are also output.

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

18: **outfile** – const char * *Input*

On entry: the name of a file to which diagnostic output will be directed. If **outfile** is **NULL** the diagnostic output will be directed to standard output.

19: **comm** – Nag_Comm *

The NAG communication argument (see Section 3.2.1.1 in the Essential Introduction).

20: **fail** – NagError * *Input/Output*

The NAG error argument (see Section 3.6 in the Essential Introduction).

6 Error Indicators and Warnings

NE_ALLOC_FAIL

Dynamic memory allocation failed.
See Section 3.2.1.2 in the Essential Introduction for further information.

NE_BAD_PARAM

On entry, argument ⟨*value*⟩ had an illegal value.

NE_INT

On entry, **ncomp** the number of connected components of the boundary is less than 1:
ncomp = ⟨*value*⟩.

On entry, **nedmx** = ⟨*value*⟩.
Constraint: **nedmx** ≥ 1.

On entry, **nedmx** the maximum number of boundary edge lines is less than 1: **nedmx** = ⟨*value*⟩.

On entry, **nlines** $= \langle value \rangle$.
Constraint: **nlines** ≥ 1.

On entry, **nlines** the number of lines is less than 1: **nlines** $= \langle value \rangle$.

NE_INT_2

On entry, **nvmax** $= \langle value \rangle$ and **nlines** $= \langle value \rangle$.
Constraint: **nvmax** $\geq$ **nlines**.

On entry, **nvmax** the maximum number of boundary vertices is less than **nlines**: **nvmax** $= \langle value \rangle$ and **nlines** $= \langle value \rangle$.

On entry, **sdcrus** $= \langle value \rangle$ and $nusmin = \langle value \rangle$.
Constraint: **sdcrus** $\geq nusmin$.

On entry, the line list for the separate connected component of the boundary is badly set: **lcomp**$[l-1] = \langle value \rangle$ and $l = \langle value \rangle$. It should be less than or equal to **nlines** and greater than or equal to 1.

On entry, the number of points on line $\langle value \rangle$ is $\langle value \rangle$. It should be greater than or equal to 2.

On entry, there is a correlation problem between the user-supplied coordinates and the specification of the polygonal arc representing line $I = \langle value \rangle$ with the index in **crus** $= \langle value \rangle$.

On entry, the sum of absolute values of all numbers of line segments is different from **nlines**. The sum of all the elements of **nlcomp** $= \langle value \rangle$. **nlines** $= \langle value \rangle$.

NE_INT_3

On entry, the absolute number of line segments in the kth component of the contour should be less than or equal to **nlines** and greater than 0. $k = \langle value \rangle$, **nlcomp**$[k-1] = \langle value \rangle$ and **nlines** $= \langle value \rangle$.

On entry, the index of the first end point of line $\langle value \rangle$ is $\langle value \rangle$. It should be greater than or equal to 1 and less than or equal to **nlines** $= \langle value \rangle$.

On entry, the index of the second end point of line $\langle value \rangle$ is $\langle value \rangle$. It should be greater than or equal to 1 and less than or equal to **nlines** $= \langle value \rangle$.

On entry, the indices of the extremities of line $\langle value \rangle$ are both equal to $\langle value \rangle$.

NE_INTERNAL_ERROR

An internal error has occurred in this function. Check the function call and any array sizes. If the call is correct then please contact NAG for assistance.

An unexpected error has been triggered by this function. Please contact NAG.
See Section 3.6.6 in the Essential Introduction for further information.

NE_MESH_ERROR

An error has occurred during the generation of the boundary mesh. It appears that **nedmx** is not large enough: **nedmx** $= \langle value \rangle$.

An error has occurred during the generation of the boundary mesh. It appears that **nvmax** is not large enough: **nvmax** $= \langle value \rangle$.

On entry, end point 1, with index K, does not lie on the curve representing line I with index J: $K = \langle value \rangle$, $I = \langle value \rangle$, $J = \langle value \rangle$, $f(x,y) = \langle value \rangle$.

On entry, end point 2, with index K, does not lie on the curve representing line I with index J: $K = \langle value \rangle$, $I = \langle value \rangle$, $J = \langle value \rangle$, $f(x,y) = \langle value \rangle$.

On entry, the geometric progression ratio between the points to be generated on line $\langle value \rangle$ is $\langle value \rangle$. It should be greater than 0 unless the line segment is defined by user-supplied points.

On entry, there is a problem with either the coordinates of characteristic points, or with the definition of the mesh lines.

NE_NO_LICENCE

Your licence key may have expired or may not have been installed correctly.
See Section 3.6.5 in the Essential Introduction for further information.

NE_NOT_CLOSE_FILE

Cannot close file ⟨*value*⟩.

NE_NOT_WRITE_FILE

Cannot open file ⟨*value*⟩ for writing.

7 Accuracy

Not applicable.

8 Parallelism and Performance

Not applicable.

9 Further Comments

The boundary mesh generation technique in this function has a ‘tree’ structure. The boundary should be partitioned into geometrically simple segments (straight lines or curves) delimited by characteristic points. Then, the lines should be assembled into connected components of the boundary domain.

Using this strategy, the inputs to that function can be built up, following the requirements stated in Section 5:

the characteristic and the user-supplied intermediate points:

nlines, **sdcrus**, **coorch** and **crus**;

the characteristic lines:

lined, **fbnd**, **rate**;

finally the assembly of lines into the connected components of the boundary:

ncomp, and

nlcomp, **lcomp**.

The example below details the use of this strategy.

10 Example

The NAG logo is taken as an example of a geometry with holes. The boundary has been partitioned in 40 lines characteristic points; including 4 for the exterior boundary and 36 for the logo itself. All line geometry specifications have been considered, see the description of **lined**, including 4 lines defined as polygonal arc, 4 defined by **fbnd** and all the others are straight lines.

10.1 Program Text

```
/* nag_mesh2d_bound (d06bac) Example Program.
 *
 * Copyright 2014 Numerical Algorithms Group.
 *
 * Mark 7, 2001.
 */

#include <stdio.h>
#include <nag.h>
#include <nag_stdlib.h>
#include <nagd06.h>
```

```
/* Structure to allow data to be passed into */
/* the user-supplied function fbnd */

struct user
{
  /* details of the ellipse containing the NAG logo */

  double xa, xb, x0, y0;
};

#ifdef __cplusplus
extern "C" {
#endif
static double NAG_CALL fbnd(Integer, double, double, Nag_Comm *);
#ifdef __cplusplus
}
#endif

#define EDGE(I, J)   edge[3*((J) -1)+(I) -1]
#define LINED(I, J)  lined[4*((J) -1)+(I) -1]
#define CONN(I, J)   conn[3*((J) -1)+(I) -1]
#define COOR(I, J)   coor[2*((J) -1)+(I) -1]
#define COORCH(I, J) coorch[2*((J) -1)+(I) -1]
#define CRUS(I, J)   crus[2*((J) -1)+(I) -1]


int main(void)
{
  const Integer sdcrus = 4, nvmax = 1000, nedmx = 300, nvint = 0;
  struct user   ellipse;
  Nag_Comm      comm;
  double        x0, xa, xb, xmax, xmin, y0, ymax, ymin;
  Integer       exit_status, i, itrace, j, k, ncomp, nedge, nelt, nlines;
  Integer       npropa, nv, nvb, reftk, l;
  char          pmesh[2];
  double        *coor = 0, *coorch = 0, *crus = 0, *rate = 0, *weight = 0;
  Integer       *conn = 0, *edge = 0, *lcomp = 0, *lined = 0, *nlcomp = 0;
  NagError      fail;

  INIT_FAIL(fail);

  exit_status = 0;

  printf(" nag_mesh2d_bound (d06bac) Example Program Results\n\n");
  fflush(stdout);

  /* Skip heading in data file */

#ifdef _WIN32
  scanf_s("%*[^\n] ");
#else
  scanf("%*[^\n] ");
#endif

  /* Initialise boundary mesh inputs: */
  /* the number of line and of the characteristic points of */
  /* the boundary mesh */

#ifdef _WIN32
  scanf_s("%"NAG_IFMT"%*[^\n] ", &nlines);
#else
  scanf("%"NAG_IFMT"%*[^\n] ", &nlines);
#endif

  /* Allocate memory */

  if (!(coor = NAG_ALLOC(2*nvmax, double)) ||
      !(coorch = NAG_ALLOC(2*nlines, double)) ||
      !(crus = NAG_ALLOC(2*sdcrus, double)) ||
      !(rate = NAG_ALLOC(nlines, double)) ||
```

```
      !(weight = NAG_ALLOC(1, double)) ||
      !(conn = NAG_ALLOC(3*(2*nvmax+5), Integer)) ||
      !(edge = NAG_ALLOC(3*nedmx, Integer)) ||
      !(lined = NAG_ALLOC(4*nlines, Integer)) ||
      !(lcomp = NAG_ALLOC(nlines, Integer)))
    {
      printf("Allocation failure\n");
      exit_status = -1;
      goto END;
    }

  /* The ellipse boundary which envelops  */
  /* the NAG Logo, the N, the A and the G */

#ifdef _WIN32
  for (j = 1; j <= nlines; ++j) scanf_s("%lf", &COORCH(1, j));
#else
  for (j = 1; j <= nlines; ++j) scanf("%lf", &COORCH(1, j));
#endif
#ifdef _WIN32
  scanf_s("%*[^\n] ");
#else
  scanf("%*[^\n] ");
#endif

#ifdef _WIN32
  for (j = 1; j <= nlines; ++j) scanf_s("%lf", &COORCH(2, j));
#else
  for (j = 1; j <= nlines; ++j) scanf("%lf", &COORCH(2, j));
#endif
#ifdef _WIN32
  scanf_s("%*[^\n] ");
#else
  scanf("%*[^\n] ");
#endif

#ifdef _WIN32
  for (j = 1; j <= sdcrus; ++j) scanf_s("%lf", &CRUS(1, j));
#else
  for (j = 1; j <= sdcrus; ++j) scanf("%lf", &CRUS(1, j));
#endif
#ifdef _WIN32
  scanf_s("%*[^\n] ");
#else
  scanf("%*[^\n] ");
#endif

#ifdef _WIN32
  for (j = 1; j <= sdcrus; ++j) scanf_s("%lf", &CRUS(2, j));
#else
  for (j = 1; j <= sdcrus; ++j) scanf("%lf", &CRUS(2, j));
#endif
#ifdef _WIN32
  scanf_s("%*[^\n] ");
#else
  scanf("%*[^\n] ");
#endif

  /* The lines of the boundary mesh */

  for (j = 1; j <= nlines; ++j)
    {
#ifdef _WIN32
      for (i = 1; i <= 4; ++i) scanf_s("%"NAG_IFMT"", &LINED(i, j));
#else
      for (i = 1; i <= 4; ++i) scanf("%"NAG_IFMT"", &LINED(i, j));
#endif
#ifdef _WIN32
      scanf_s("%lf", &rate[j-1]);
#else
      scanf("%lf", &rate[j-1]);
```

```
#endif
    }
#ifdef _WIN32
  scanf_s("%*[^\n] ");
#else
  scanf("%*[^\n] ");
#endif

  /* The number of connected components  */
  /* to the boundary and their information */

#ifdef _WIN32
  scanf_s("%"NAG_IFMT"%*[^\n] ", &ncomp);
#else
  scanf("%"NAG_IFMT"%*[^\n] ", &ncomp);
#endif

  /* Allocate memory */

  if (!(nlcomp = NAG_ALLOC(ncomp, Integer)))
    {
      printf("Allocation failure\n");
      exit_status = -1;
      goto END;
    }

  j = 0;
  for (i = 0; i < ncomp; ++i)
    {
#ifdef _WIN32
      scanf_s("%"NAG_IFMT"", &nlcomp[i]);
#else
      scanf("%"NAG_IFMT"", &nlcomp[i]);
#endif
#ifdef _WIN32
      scanf_s("%*[^\n] ");
#else
      scanf("%*[^\n] ");
#endif
      l = j + abs(nlcomp[i]);

#ifdef _WIN32
      for (k = j; k < l; ++k) scanf_s("%"NAG_IFMT"", &lcomp[k]);
#else
      for (k = j; k < l; ++k) scanf("%"NAG_IFMT"", &lcomp[k]);
#endif
#ifdef _WIN32
      scanf_s("%*[^\n] ");
#else
      scanf("%*[^\n] ");
#endif

      j += abs(nlcomp[i]);
    }

#ifdef _WIN32
  scanf_s(" ' %1s '%*[^\n] ", pmesh, _countof(pmesh));
#else
  scanf(" ' %1s '%*[^\n] ", pmesh);
#endif

  /* Data passed to the user-supplied function */

  xmin = COORCH(1, 4);
  xmax = COORCH(1, 2);
  ymin = COORCH(2, 1);
  ymax = COORCH(2, 3);

  xa = (xmax-xmin)/2.0;
  xb = (ymax-ymin)/2.0;
```

```
x0 = (xmin+xmax)/2.0;
y0 = (ymin+ymax)/2.0;

comm.p = (Pointer)&ellipse;

ellipse.xa = xa;
ellipse.xb = xb;
ellipse.x0 = x0;
ellipse.y0 = y0;

itrace = -1;

/* Call to the boundary mesh generator */

/* nag_mesh2d_bound (d06bac).
 * Generates a boundary mesh
 */
nag_mesh2d_bound(nlines, coorch, lined, fbnd, crus, sdcrus, rate, ncomp,
                 nlcomp, lcomp, nvmax, nedmx, &nvb, coor, &nedge, edge,
                 itrace, 0, &comm, &fail);
if (fail.code == NE_NOERROR)
  {
    if (pmesh[0] == 'N')
      {
        printf(" Boundary mesh characteristics\n");
        printf(" nvb   =%6"NAG_IFMT"\n", nvb);
        printf(" nedge =%6"NAG_IFMT"\n", nedge);
      }
    else if (pmesh[0] == 'Y')
      {
        /* Output the mesh to view it using the NAG Graphics Library */

        printf(" %10"NAG_IFMT"%10"NAG_IFMT"\n", nvb, nedge);

        for (i = 1; i <= nvb; ++i)
          printf("  %4"NAG_IFMT"  %15.6e  %15.6e  \n",
                  i, COOR(1, i), COOR(2, i));

        for (i = 1; i <= nedge; ++i)
          printf(" %4"NAG_IFMT"%4"NAG_IFMT"%4"NAG_IFMT"%4"NAG_IFMT"\n",
                  i, EDGE(1, i), EDGE(2, i), EDGE(3, i));
      }
    else
      {
        printf("Problem with the printing option Y or N\n");
        exit_status = -1;
        goto END;
      }
  }
else
  {
    printf("Error from nag_mesh2d_bound (d06bac).\n%s\n",
            fail.message);
    exit_status = 1;
    goto END;
  }

/* Initialise mesh control parameters */

itrace = 0;
npropa = 1;

/* Call to the 2D Delaunay-Voronoi mesh generator */

/* nag_mesh2d_delaunay (d06abc).
 * Generates a two-dimensional mesh using a Delaunay-Voronoi
 * process
 */
nag_mesh2d_delaunay(nvb, nvint, nvmax, nedge, edge, &nv, &nelt, coor, conn,
                    weight, npropa, itrace, 0, &fail);
if (fail.code == NE_NOERROR)
```

```
    {
      if (pmesh[0] == 'N')
        {
          printf(" Complete mesh characteristics (Delaunay-Voronoi)\n");
          printf(" nv   =%6"NAG_IFMT"\n", nv);
          printf(" nelt =%6"NAG_IFMT"\n", nelt);
        }
      else if (pmesh[0] == 'Y')
        {
          /* Output the mesh to view it using the NAG Graphics Library */

          printf(" %10"NAG_IFMT"%10"NAG_IFMT"\n", nv, nelt);

          for (i = 1; i <= nv; ++i)
            printf("  %15.6e  %15.6e  \n", COOR(1, i), COOR(2, i));

          reftk = 0;
          for (k = 1; k <= nelt; ++k)
            printf(" %10"NAG_IFMT"%10"NAG_IFMT"%10"NAG_IFMT"%10"NAG_IFMT"\n",
                    CONN(1, k), CONN(2, k), CONN(3, k), reftk);
        }
      else
        {
          printf("Problem with the printing option Y or N\n");
          exit_status = -1;
          goto END;
        }
    }
  else
    {
      printf("Error from nag_mesh2d_delaunay (d06abc).\n%s\n",
              fail.message);
      exit_status = 1;
      goto END;
    }

  /* Call to the 2D Advancing front mesh generator */

  /* nag_mesh2d_front (d06acc).
   * Generates a two-dimensional mesh using an Advancing-front
   * method
   */
  nag_mesh2d_front(nvb, nvint, nvmax, nedge, edge, &nv, &nelt, coor,
                   conn, weight, itrace, 0, &fail);
  if (fail.code == NE_NOERROR)
    {
      if (pmesh[0] == 'N')
        {
          printf(" Complete mesh characteristics (Advancing Front)\n");
          printf(" nv   =%6"NAG_IFMT"\n", nv);
          printf(" nelt =%6"NAG_IFMT"\n", nelt);
        }
      else if (pmesh[0] == 'Y')
        {
          /* Output the mesh to view it using the NAG Graphics Library */

          printf(" %10"NAG_IFMT"%10"NAG_IFMT"\n", nv, nelt);

          for (i = 1; i <= nv; ++i)
            printf("  %15.6e  %15.6e  \n",
                    COOR(1, i), COOR(2, i));

          reftk = 0;
          for (k = 1; k <= nelt; ++k)
            printf(" %10"NAG_IFMT"%10"NAG_IFMT"%10"NAG_IFMT"%10"NAG_IFMT"\n",
                    CONN(1, k), CONN(2, k), CONN(3, k), reftk);
        }
      else
        {
          printf("Problem with the printing option Y or N\n");
          exit_status = -1;
```

```
          goto END;
        }
    }
  else
    {
      printf("Error from nag_mesh2d_front (d06acc).\n%s\n",
              fail.message);
      exit_status = 1;
      goto END;
    }

 END:
  NAG_FREE(coor);
  NAG_FREE(coorch);
  NAG_FREE(crus);
  NAG_FREE(rate);
  NAG_FREE(weight);
  NAG_FREE(conn);
  NAG_FREE(edge);
  NAG_FREE(lcomp);
  NAG_FREE(lined);
  NAG_FREE(nlcomp);

  return exit_status;
}

static double NAG_CALL fbnd(Integer i, double x, double y, Nag_Comm *pcomm)
{
  double      ret_val, d1, d2;
  double      radius2, x0, xa, xb, y0;
  struct user *ellipse = (struct user *) pcomm->p;

  xa = ellipse->xa;
  xb = ellipse->xb;
  x0 = ellipse->x0;
  y0 = ellipse->y0;

  ret_val = 0.0;

  switch (i)
    {
    case 1:

      /* line 1,2,3, and 4: ellipse centred in (X0,Y0) with */
      /* XA and XB as coefficients */

      d1 = (x - x0)/xa;
      d2 = (y - y0)/xb;

      ret_val = d1*d1 + d2*d2 - 1.0;
      break;

    case 2:

      /* line 24, 27, 33 and 38 are a circle centred in (X0,Y0) */
      /* with radius SQRT(RADIUS2) */

      x0 = 20.5;
      y0 = 4.0;
      radius2 = 4.25;

      d1 = x - x0;
      d2 = y - y0;

      ret_val = d1*d1 + d2*d2 - radius2;
      break;

    case 3:

      x0 = 17.0;
      y0 = 8.5;
```

```
      radius2 = 5.0;

      d1 = x - x0;
      d2 = y - y0;

      ret_val = d1*d1 + d2*d2 - radius2;
      break;

    case 4:

      x0 = 17.0;
      y0 = 8.5;
      radius2 = 5.0;

      d1 = x - x0;
      d2 = y - y0;

      ret_val = d1*d1 + d2*d2 - radius2;
      break;

    case 5:

      x0 = 19.5;
      y0 = 4.0;
      radius2 = 1.25;

      d1 = x - x0;
      d2 = y - y0;

      ret_val = d1*d1 + d2*d2 - radius2;
      break;

    default:
      break;
    }

  return ret_val;
}
```

10.2 Program Data

```
nag_mesh2d_bound (d06bac) Example Program Data
40                                                            :NLINES (m)
  9.5000  33.0000   9.5000 -14.0000  -4.0000  -2.0000   2.0000
  4.0000   2.0000  -2.0000  -4.0000  -2.0000   2.0000   4.0000
  7.0000   9.0000  13.0000  16.0000   9.0000  12.0000   7.0000
 10.0000  18.0000  21.0000  17.0000  20.0000  16.0000  20.0000
 15.5000  16.0000  18.0000  21.0000  16.0000  18.0000  18.5811
 21.0000  17.0000  20.0000  20.5000  23.0000          :(COORCH(1,1:m))
 -1.0000   7.5000  16.0000   7.5000   3.0000   3.0000   3.0000
  3.0000   7.0000   8.0000  12.0000  12.0000  12.0000  12.0000
  3.0000   3.0000   3.0000   3.0000   5.0000   5.0000  12.0000
 12.0000   2.0000   2.0000   3.0000   3.0000   5.0000   5.0000
  6.0000   6.0000   6.0000   6.0000   6.5000   6.5000  10.0811
 10.0811  10.7361  10.7361  12.0000  12.0000          :(COORCH(2,1:m))
 -2.6667  -3.3333   3.3333   2.6667                   :(COORUS(1,1:4))
  3.0000   3.0000   3.0000   3.0000                   :(COORUS(2,1:4))
15  1  2  1   0.9500   15  2  3  1   1.0500
15  3  4  1   0.9500   15  4  1  1   1.0500
 4  6  5 -1   1.0000   10 10  6  0   1.0000
10  7 10  0   1.0000    4  8  7 -3   1.0000
15 14  8  0   1.0000    4 13 14  0   1.0000
10  9 13  0   1.0000   10 12  9  0   1.0000
 4 11 12  0   1.0000   15  5 11  0   1.0000
 4 16 15  0   1.0000    7 19 16  0   1.0000
 4 20 19  0   1.0000    7 17 20  0   1.0000
 4 18 17  0   1.0000   13 22 18  0   1.0000
 5 21 22  0   1.0000   13 15 21  0   1.0000
 4 24 23  0   1.0000   10 24 32  2   1.0000
 4 31 32  0   1.0000    4 34 31  0   1.0000
```

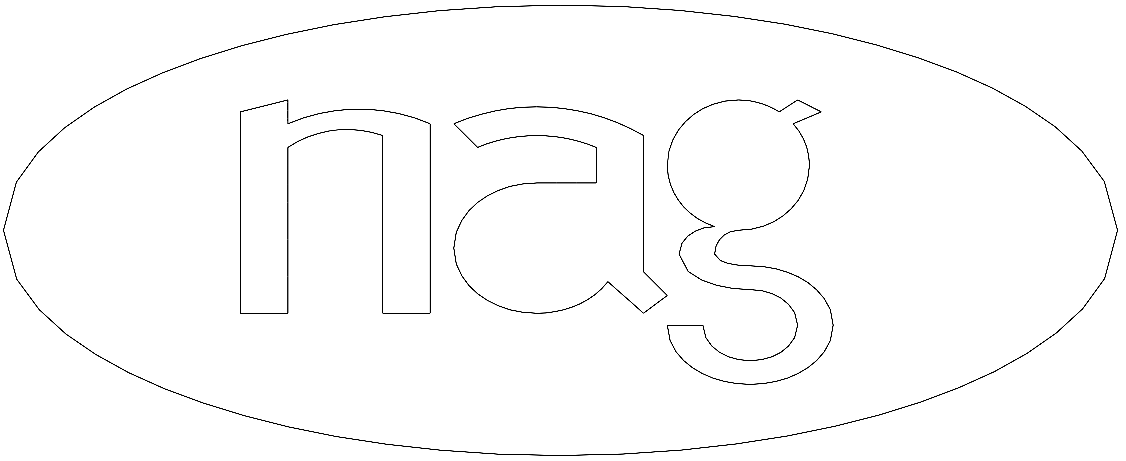
```
10 34 35  3   1.0000    4 36 35  0   1.0000
 4 40 36  0   1.0000    4 39 40  0   1.0000
 4 38 39  0   1.0000    4 37 38  0   1.0000
10 37 33  4   1.0000    4 30 33  0   1.0000
 4 29 30  0   1.0000    4 27 29  0   1.0000
 4 28 27  0   1.0000   10 26 28  5   1.0000
 4 25 26  0   1.0000    4 23 25  0   1.0000 :(LINE(:,j),RATE(j),j=1,m)
 4                                        :NCOMP (n, number of contours)
 4                                         :number of lines in contour 1
 1  2  3  4                                          :lines of contour 1
10                                         :number of lines in contour 2
14 13 12 11 10  9  8  7  6  5                        :lines of contour 2
 8                                         :number of lines in contour 3
22 21 20 19 18 17 16 15                              :lines of contour 3
18                                         :number of lines in contour 4
30 29 28 27 26 25 24 23 40 39
38 37 36 35 34 33 32 31                              :lines of contour 4
'N'                                           :Printing option 'Y' or 'N'
```

10.3 Program Results

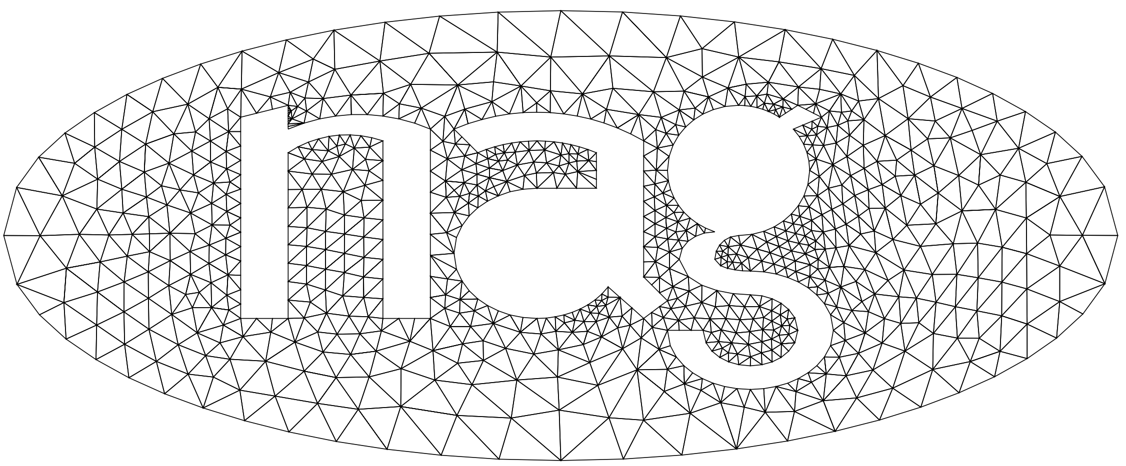
```
nag_mesh2d_bound (d06bac) Example Program Results

Analysis of the boundary created:
The boundary mesh contains    259 vertices and    259 edges
There are      4 components comprising the boundary:
The  1-st component contains      4 lines in anticlockwise orientation
The  2-nd component contains     10 lines in     clockwise orientation
The  3-rd component contains      8 lines in     clockwise orientation
The  4-th component contains     18 lines in     clockwise orientation
Boundary mesh characteristics
nvb   =   259
nedge =   259
Complete mesh characteristics (Delaunay-Voronoi)
nv    =   652
nelt =  1049
Complete mesh characteristics (Advancing Front)
nv    =   662
nelt =  1069
```

Example Program
Boundary Mesh of the NAG Logo with 259 Nodes and 259 Edges



Final Mesh Built Using the Delaunay-Voronoi Method



Final Mesh Built Using the Advancing Front Method