NAG Library Function Document

nag_mesh2d_delaunay (d06abc)

1 Purpose

nag_mesh2d_delaunay (d06abc) generates a triangular mesh of a closed polygonal region in $\mathbb{R}^2$, given a mesh of its boundary. It uses a Delaunay–Voronoi process, based on an incremental method.

2 Specification

```
#include <nag.h>
#include <nagd06.h>
void nag_mesh2d_delaunay (Integer nvb, Integer nvint, Integer nvmax,
     Integer nedge, const Integer edge[], Integer *nv, Integer *nelt,
     double coor[], Integer conn[], const double weight[], Integer npropa,
     Integer itrace, const char *outfile, NagError *fail)
```

3 Description

nag_mesh2d_delaunay (d06abc) generates the set of interior vertices using a Delaunay–Voronoi process, based on an incremental method. It allows you to specify a number of fixed interior mesh vertices together with weights which allow concentration of the mesh in their neighbourhood. For more details about the triangulation method, 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: **nvb** – Integer *Input*

On entry: the number of vertices in the input boundary mesh.

Constraint: **nvb** ≥ 3.

2: **nvint** – Integer *Input*

On entry: the number of fixed interior mesh vertices to which a weight will be applied.

Constraint: **nvint** ≥ 0.

3: **nvmax** – Integer *Input*

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

Constraint: **nvmax** $\geq$ **nvb** + **nvint**.

4: **nedge** – Integer *Input*

On entry: the number of boundary edges in the input mesh.

Constraint: **nedge** ≥ 1.

5: **edge**[**3** × **nedge**] – const Integer *Input*

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

On entry: the specification of the boundary edges. **edge**$[(j-1)\times 3]$ and **edge**$[(j-1)\times 3+1]$ contain the vertex numbers of the two end points of the jth boundary edge. **edge**$[(j-1)\times 3+2]$ is a user-supplied tag for the jth boundary edge and is not used by nag_mesh2d_delaunay (d06abc). Note that the edge vertices are numbered from 1 to **nvb**.

Constraint: $1 \leq$ **edge**$[(j-1)\times 3+i-1] \leq$ **nvb** and **edge**$[(j-1)\times 3] \neq$ **edge**$[(j-1)\times 3+1]$, for $i = 1,2$ and $j = 1,2,\ldots,$ **nedge**.

6: **nv** – Integer * *Output*

On exit: the total number of vertices in the output mesh (including both boundary and interior vertices). If **nvb** + **nvint** = **nvmax**, no interior vertices will be generated and **nv** = **nvmax**.

7: **nelt** – Integer * *Output*

On exit: the number of triangular elements in the mesh.

8: **coor**[**2** × **nvmax**] – double *Input/Output*

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

On entry: **coor**$[(i-1)\times 2]$ contains the x coordinate of the ith input boundary mesh vertex, for $i = 1,2,\ldots,$ **nvb**. **coor**$[(i-1)\times 2]$ contains the x coordinate of the $(i-$ **nvb**$)$th fixed interior vertex, for $i =$ **nvb** $+1,\ldots,$ **nvb** + **nvint**. For boundary and interior vertices, **coor**$[(i-1)\times 2+1]$ contains the corresponding y coordinate, for $i = 1,2,\ldots,$ **nvb** + **nvint**.

On exit: **coor**$[(i-1)\times 2]$ will contain the x coordinate of the $(i-$ **nvb** $-$ **nvint**$)$th generated interior mesh vertex, for $i =$ **nvb** + **nvint** $+1,\ldots,$ **nv**; while **coor**$[(i-1)\times 2+1]$ will contain the corresponding y coordinate. The remaining elements are unchanged.

9: **conn**[**3** × (**2** × **nvmax** + **5**)] – Integer *Output*

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

On exit: the connectivity of the mesh between triangles and vertices. For each triangle j, **conn**$[(j-1)\times 3+i-1]$ gives the indices of its three vertices (in anticlockwise order), for $i = 1,2,3$ and $j = 1,2,\ldots,$ **nelt**. Note that the mesh vertices are numbered from 1 to **nv**.

10: **weight**$[dim]$ – const double *Input*

Note: the dimension, *dim*, of the array **weight** must be at least $\max(1,$ **nvint**$)$.

On entry: the weight of fixed interior vertices. It is the diameter of triangles (length of the longer edge) created around each of the given interior vertices.

Constraint: if **nvint** > 0, **weight**$[i-1] > 0.0$, for $i = 1,2,\ldots,$ **nvint**.

11: **npropa** – Integer *Input*

On entry: the propagation type and coefficient, the argument **npropa** is used when the internal points are created. They are distributed in a geometric manner if **npropa** is positive and in an arithmetic manner if it is negative. For more details see Section 9.

Constraint: **npropa** $\neq 0$.

12: **itrace** – Integer *Input*

On entry: the level of trace information required from nag_mesh2d_delaunay (d06abc).

itrace ≤ 0
No output is generated.

itrace ≥ 1
Output from the meshing solver is printed. This output contains details of the vertices and triangles generated by the process.

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

13: **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.

14: **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, **nedge** $= \langle value \rangle$.
Constraint: **nedge** ≥ 1.

On entry, **npropa** $= 0$.

On entry, **nvb** $= \langle value \rangle$.
Constraint: **nvb** ≥ 3.

On entry, **nvint** $= \langle value \rangle$.
Constraint: **nvint** ≥ 0.

NE_INT_2

On entry, the endpoints of the edge J have the same index I: $J = \langle value \rangle$ and $I = \langle value \rangle$.

NE_INT_3

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

NE_INT_4

On entry, **EDGE**$(I, J) = \langle value \rangle$, $I = \langle value \rangle$, $J = \langle value \rangle$ and **nvb** $= \langle value \rangle$.
Constraint: **EDGE**$(I, J) \geq 1$ and **EDGE**$(I, J) \leq$ **nvb**, where **EDGE**(I, J) denotes **edge**$[(J-1) \times 3 + I - 1]$.

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 **nvmax** is not large enough: **nvmax** $= \langle value \rangle$.

An error has occurred during the generation of the interior mesh. Check the inputs of the boundary.

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 $\langle value \rangle$.

NE_NOT_WRITE_FILE

Cannot open file $\langle value \rangle$ for writing.

NE_REAL_ARRAY_INPUT

On entry, **weight**$[I-1] = \langle value \rangle$ and $I = \langle value \rangle$.
Constraint: **weight**$[I-1] > 0.0$.

7 Accuracy

Not applicable.

8 Parallelism and Performance

nag_mesh2d_delaunay (d06abc) is not threaded by NAG in any implementation.

nag_mesh2d_delaunay (d06abc) makes calls to BLAS and/or LAPACK routines, which may be threaded within the vendor library used by this implementation. Consult the documentation for the vendor library for further information.

Please consult the X06 Chapter Introduction for information on how to control and interrogate the OpenMP environment used within this function. Please also consult the Users' Note for your implementation for any additional implementation-specific information.

9 Further Comments

The position of the internal vertices is a function position of the vertices on the given boundary. A fine mesh on the boundary results in a fine mesh in the interior. To dilute the influence of the data on the interior of the domain, the value of **npropa** can be changed. The propagation coefficient is calculated as: $\omega = 1 + \dfrac{a - 1.0}{20.0}$, where a is the absolute value of **npropa**. During the process vertices are generated on edges of the mesh $\mathcal{T}_i$ to obtain the mesh $\mathcal{T}_{i+1}$ in the general incremental method (consult the d06 Chapter Introduction or George and Borouchaki (1998)). This generation uses the coefficient ω, and it is geometric if **npropa** > 0, and arithmetic otherwise. But increasing the value of a may lead to failure of the process, due to precision, especially in geometries with holes. So you are advised to manipulate the argument **npropa** with care.

You are advised to take care to set the boundary inputs properly, especially for a boundary with multiply connected components. The orientation of the interior boundaries should be in **clockwise** order and opposite to that of the exterior boundary. If the boundary has only one connected component, its orientation should be **anticlockwise**.

10 Example

In this example, a geometry with two holes (two wings inside an exterior circle) is meshed using a Delaunay–Voronoi method. The exterior circle is centred at the point $(1.0, 0.0)$ with a radius 3. The main wing, using aerofoil RAE 2822 data, lies between the origin and the centre of the circle, while the secondary aerofoil is produced from the first by performing a translation, a scale reduction and a rotation. To be able to carry out some realistic computation on that geometry, some interior points have been introduced to have a finer mesh in the wake of those aerofoils.

The boundary mesh has 296 vertices and 296 edges (see Section 10.3 top). Note that the particular mesh generated could be sensitive to the ***machine precision*** and therefore may differ from one implementation to another. The interior meshes for different values of **npropa** are given in Section 10.3.

10.1 Program Text

```
/* nag_mesh2d_delaunay (d06abc) Example Program.
 *
 * Copyright 2014 Numerical Algorithms Group.
 *
 * Mark 7, 2001.
 */

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

#define EDGE(I, J) edge[3*((J) -1)+(I) -1]
#define CONN(I, J) conn[3*((J) -1)+(I) -1]
#define COOR(I, J) coor[2*((J) -1)+(I) -1]

int main(void)
{
  const Integer nvmax = 6000, nvint = 40;
  double        dnvint;
  Integer       exit_status, i, itrace, j, k, nedge, nelt,
                npropa, nv, nvb, reftk, i1;
  NagError      fail;
  char          pmesh[2];
  double        *coor = 0, *weight = 0;
  Integer       *conn = 0, *edge = 0;

  INIT_FAIL(fail);

  exit_status = 0;

  printf("nag_mesh2d_delaunay (d06abc) Example Program Results\n\n");

  /* Skip heading in data file */

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

  /* Reading of the geometry */

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

  if (nvb > nvmax)
    {
      printf("Problem with the array dimensions\n");
      printf(" nvb nvmax %6"NAG_IFMT"%6"NAG_IFMT"\n", nvb, nvmax);
```

```
      printf(" Please increase the value of nvmax\n");
      exit_status = -1;
      goto END;
    }

  /* Allocate memory */

  if (!(coor = NAG_ALLOC(2*nvmax, double)) ||
      !(weight = NAG_ALLOC(nvint, double)) ||
      !(conn = NAG_ALLOC(3*(2*nvmax + 5), Integer)) ||
      !(edge = NAG_ALLOC(3*nedge, Integer)))
    {
      printf("Allocation failure\n");
      exit_status = -1;
      goto END;
    }

  /* Coordinates of the boundary mesh vertices and boundary edges */

  for (i = 1; i <= nvb; ++i)
    {
#ifdef _WIN32
      scanf_s("%"NAG_IFMT"", &i1);
#else
      scanf("%"NAG_IFMT"", &i1);
#endif
#ifdef _WIN32
      scanf_s("%lf", &COOR(1, i1));
#else
      scanf("%lf", &COOR(1, i1));
#endif
#ifdef _WIN32
      scanf_s("%lf", &COOR(2, i1));
#else
      scanf("%lf", &COOR(2, i1));
#endif
#ifdef _WIN32
      scanf_s("%*[^\n] ");
#else
      scanf("%*[^\n] ");
#endif
    }

  for (i = 1; i <= nedge; ++i)
    {
#ifdef _WIN32
      scanf_s("%"NAG_IFMT"", &i1);
#else
      scanf("%"NAG_IFMT"", &i1);
#endif
#ifdef _WIN32
      scanf_s("%"NAG_IFMT"", &EDGE(1, i1));
#else
      scanf("%"NAG_IFMT"", &EDGE(1, i1));
#endif
#ifdef _WIN32
      scanf_s("%"NAG_IFMT"", &EDGE(2, i1));
#else
      scanf("%"NAG_IFMT"", &EDGE(2, i1));
#endif
#ifdef _WIN32
      scanf_s("%"NAG_IFMT"", &EDGE(3, i1));
#else
      scanf("%"NAG_IFMT"", &EDGE(3, i1));
#endif
#ifdef _WIN32
      scanf_s("%*[^\n] ");
#else
      scanf("%*[^\n] ");
#endif
    }
```

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

  /* Initialise mesh control parameters */

  itrace = 0;

  /* Generation of interior vertices on the RAE airfoils wake */

  dnvint = 2.5/(double)(nvint + 1);

  for (i = 1; i <= nvint; ++i)
    {
      i1 = nvb + i;
      COOR(1, i1) = (double) i*dnvint + 1.38;
      COOR(2, i1) = -0.27*COOR(1, i1) + 0.2;
      weight[i-1] = 0.01;
    }

  /* Loop on the propagation coef */

  for (j = 0; j < 4; ++j)
    {
      switch (j)
        {
        case 0:
          npropa = -5;
          break;
        case 1:
          npropa = -1;
          break;
        case 2:
          npropa = 1;
          break;
        default:
          npropa = 5;
        }

      /* 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(" Mesh characteristics with npropa =%6"NAG_IFMT"\n",
                      npropa);
              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;
        }
    }

 END:
  NAG_FREE(coor);
  NAG_FREE(weight);
  NAG_FREE(conn);
  NAG_FREE(edge);

  return exit_status;
}
```

10.2 Program Data

Note 1: since the data file for this example is quite large only a section of it is reproduced in this document. The full data file is distributed with your implementation.

```
nag_mesh2d_delaunay (d06abc) Example Program Data
       296       296     :NVB NEDGE
     1  0.400000E+01  0.000000E+00
     2  0.396307E+01  0.469303E+00
     3  0.385317E+01  0.927051E+00
     4  0.367302E+01  0.136197E+01
     5  0.342705E+01  0.176336E+01
     6  0.312132E+01  0.212132E+01
     7  0.276336E+01  0.242705E+01
     8  0.236197E+01  0.267302E+01
     9  0.192705E+01  0.285317E+01
    10  0.146930E+01  0.296307E+01
    11  0.100000E+01  0.300000E+01
    12  0.530697E+00  0.296307E+01
    13  0.729490E-01  0.285317E+01
    14  -.361971E+00  0.267302E+01
    15  -.763356E+00  0.242705E+01
    16  -.112132E+01  0.212132E+01
    17  -.142705E+01  0.176336E+01
    18  -.167302E+01  0.136197E+01
    19  -.185317E+01  0.927051E+00
    20  -.196307E+01  0.469303E+00
    21  -.200000E+01  0.367394E-15
    22  -.196307E+01  -.469303E+00
    23  -.185317E+01  -.927051E+00
    24  -.167302E+01  -.136197E+01
    25  -.142705E+01  -.176336E+01
    26  -.112132E+01  -.212132E+01
    27  -.763356E+00  -.242705E+01
    28  -.361971E+00  -.267302E+01
    29  0.729490E-01  -.285317E+01
```

30	0.530697E+00	-.296307E+01
31	0.100000E+01	-.300000E+01
32	0.146930E+01	-.296307E+01
33	0.192705E+01	-.285317E+01
34	0.236197E+01	-.267302E+01
35	0.276336E+01	-.242705E+01
36	0.312132E+01	-.212132E+01
37	0.342705E+01	-.176336E+01
38	0.367302E+01	-.136197E+01
39	0.385317E+01	-.927051E+00
40	0.396307E+01	-.469303E+00
41	0.000000E+00	0.000000E+00
42	0.602000E-03	0.316500E-02
43	0.240800E-02	0.630600E-02
44	0.541200E-02	0.941600E-02
45	0.960700E-02	0.124800E-01
46	0.149840E-01	0.154890E-01
47	0.215300E-01	0.184410E-01
48	0.292280E-01	0.213480E-01
49	0.380600E-01	0.242190E-01
50	0.480050E-01	0.270620E-01
51	0.590390E-01	0.298740E-01
52	0.711360E-01	0.326440E-01
53	0.842650E-01	0.353600E-01
54	0.983960E-01	0.380110E-01
55	0.113495E+00	0.405850E-01
56	0.129524E+00	0.430710E-01
57	0.146447E+00	0.454570E-01
58	0.164221E+00	0.477290E-01
59	0.182803E+00	0.498740E-01
60	0.202150E+00	0.518850E-01
61	0.222215E+00	0.537530E-01
62	0.242949E+00	0.554700E-01
63	0.264302E+00	0.570260E-01
64	0.286222E+00	0.584140E-01
65	0.308658E+00	0.596290E-01
66	0.331555E+00	0.606600E-01
67	0.354858E+00	0.614970E-01
68	0.378510E+00	0.621330E-01
69	0.402455E+00	0.625620E-01
70	0.426635E+00	0.627790E-01
71	0.450991E+00	0.627740E-01
72	0.475466E+00	0.625300E-01
73	0.500000E+00	0.620290E-01
74	0.524534E+00	0.612540E-01
75	0.549009E+00	0.601940E-01
76	0.573365E+00	0.588450E-01
77	0.597545E+00	0.572180E-01
78	0.621490E+00	0.553440E-01
79	0.645142E+00	0.532580E-01
80	0.668445E+00	0.509930E-01
81	0.691342E+00	0.485750E-01
82	0.713778E+00	0.460290E-01
83	0.735698E+00	0.433770E-01
84	0.757051E+00	0.406410E-01
85	0.777785E+00	0.378470E-01
86	0.797850E+00	0.350170E-01
87	0.817197E+00	0.321760E-01
88	0.835779E+00	0.293470E-01
89	0.853553E+00	0.265540E-01
90	0.870476E+00	0.238170E-01
91	0.886505E+00	0.211530E-01
92	0.901604E+00	0.185800E-01
93	0.915735E+00	0.161130E-01
94	0.928864E+00	0.137690E-01
95	0.940961E+00	0.115620E-01
96	0.951995E+00	0.950800E-02
97	0.961940E+00	0.762200E-02
98	0.970772E+00	0.591500E-02
99	0.978470E+00	0.440100E-02
100	0.985016E+00	0.309200E-02

```
  101  0.990393E+00  0.200100E-02
  102  0.994588E+00  0.113700E-02
  103  0.997592E+00  0.510000E-03
  104  0.999398E+00  0.128000E-03
  105  0.100000E+01  0.000000E+00
  106  0.999398E+00  0.350000E-04
  107  0.997592E+00  0.137000E-03
  108  0.994588E+00  0.296000E-03
  109  0.990393E+00  0.497000E-03
  110  0.985016E+00  0.719000E-03
  111  0.978470E+00  0.935000E-03
  112  0.970772E+00  0.111200E-02
  113  0.961940E+00  0.121200E-02
  114  0.951995E+00  0.119700E-02
  115  0.940961E+00  0.103300E-02
  116  0.928864E+00  0.694000E-03
  117  0.915735E+00  0.157000E-03
  118  0.901604E+00  -.600000E-03
  119  0.886505E+00  -.159200E-02
  120  0.870476E+00  -.282900E-02
  121  0.853553E+00  -.431400E-02
  122  0.835779E+00  -.604800E-02
  123  0.817197E+00  -.802700E-02
  124  0.797850E+00  -.102440E-01
  125  0.777785E+00  -.126900E-01
  126  0.757051E+00  -.153570E-01
  127  0.735698E+00  -.182320E-01
  128  0.713778E+00  -.212890E-01
  129  0.691342E+00  -.244950E-01
  130  0.668445E+00  -.278140E-01
  131  0.645142E+00  -.312070E-01
  132  0.621490E+00  -.346310E-01
  133  0.597545E+00  -.380430E-01
  134  0.573365E+00  -.413970E-01
  135  0.549009E+00  -.446420E-01
  136  0.524534E+00  -.477190E-01
  137  0.500000E+00  -.505630E-01
  138  0.475466E+00  -.530990E-01
  139  0.450991E+00  -.552570E-01
  140  0.426635E+00  -.569790E-01
  141  0.402455E+00  -.582240E-01
  142  0.378510E+00  -.589740E-01
  143  0.354858E+00  -.592360E-01
  144  0.331555E+00  -.590460E-01
  145  0.308658E+00  -.584590E-01
  146  0.286222E+00  -.575470E-01
  147  0.264302E+00  -.563760E-01
  148  0.242949E+00  -.549940E-01
  149  0.222215E+00  -.534270E-01
  150  0.202150E+00  -.516940E-01
  151  0.182803E+00  -.498050E-01
  152  0.164221E+00  -.477730E-01
  153  0.146447E+00  -.456100E-01
  154  0.129524E+00  -.433260E-01
  155  0.113495E+00  -.409290E-01
  156  0.983960E-01  -.384310E-01
  157  0.842650E-01  -.358430E-01
  158  0.711360E-01  -.331700E-01
  159  0.590390E-01  -.304160E-01
  160  0.480050E-01  -.275860E-01
  161  0.380600E-01  -.246850E-01
  162  0.292280E-01  -.217220E-01
  163  0.215300E-01  -.187070E-01
  164  0.149840E-01  -.156490E-01
  165  0.960700E-02  -.125590E-01
  166  0.541200E-02  -.944300E-02
  167  0.240800E-02  -.630800E-02
  168  0.602000E-03  -.316000E-02
  169  0.991481E+00  -.647048E-01
  170  0.992042E+00  -.635442E-01
  171  0.993065E+00  -.625176E-01
```

```
172  0.994547E+00  -.616270E-01
173  0.996485E+00  -.608774E-01
174  0.998874E+00  -.602715E-01
175  0.100171E+01  -.598087E-01
176  0.100498E+01  -.594824E-01
177  0.100869E+01  -.592875E-01
178  0.101283E+01  -.592187E-01
179  0.101739E+01  -.592745E-01
180  0.102235E+01  -.594566E-01
181  0.102770E+01  -.597665E-01
182  0.103343E+01  -.602051E-01
183  0.103953E+01  -.607738E-01
184  0.104598E+01  -.614727E-01
185  0.105277E+01  -.623028E-01
186  0.105987E+01  -.632651E-01
187  0.106727E+01  -.643601E-01
188  0.107496E+01  -.655860E-01
189  0.108290E+01  -.669416E-01
190  0.109109E+01  -.684247E-01
191  0.109950E+01  -.700342E-01
192  0.110812E+01  -.717672E-01
193  0.111691E+01  -.736205E-01
194  0.112586E+01  -.755926E-01
195  0.113495E+01  -.776817E-01
196  0.114416E+01  -.798847E-01
197  0.115346E+01  -.821979E-01
198  0.116282E+01  -.846173E-01
199  0.117223E+01  -.871408E-01
200  0.118166E+01  -.897689E-01
201  0.119109E+01  -.925024E-01
202  0.120049E+01  -.953418E-01
203  0.120983E+01  -.982852E-01
204  0.121910E+01  -.101328E+00
205  0.122828E+01  -.104460E+00
206  0.123734E+01  -.107663E+00
207  0.124626E+01  -.110917E+00
208  0.125503E+01  -.114205E+00
209  0.126362E+01  -.117510E+00
210  0.127203E+01  -.120816E+00
211  0.128022E+01  -.124110E+00
212  0.128819E+01  -.127378E+00
213  0.129591E+01  -.130604E+00
214  0.130337E+01  -.133775E+00
215  0.131055E+01  -.136875E+00
216  0.131744E+01  -.139892E+00
217  0.132402E+01  -.142811E+00
218  0.133027E+01  -.145621E+00
219  0.133619E+01  -.148310E+00
220  0.134176E+01  -.150867E+00
221  0.134696E+01  -.153283E+00
222  0.135179E+01  -.155548E+00
223  0.135624E+01  -.157653E+00
224  0.136029E+01  -.159589E+00
225  0.136394E+01  -.161347E+00
226  0.136717E+01  -.162921E+00
227  0.136999E+01  -.164303E+00
228  0.137238E+01  -.165486E+00
229  0.137435E+01  -.166465E+00
230  0.137588E+01  -.167233E+00
231  0.137697E+01  -.167786E+00
232  0.137763E+01  -.168121E+00
233  0.137785E+01  -.168232E+00
234  0.137762E+01  -.168157E+00
235  0.137694E+01  -.167930E+00
236  0.137579E+01  -.167558E+00
237  0.137419E+01  -.167046E+00
238  0.137214E+01  -.166403E+00
239  0.136963E+01  -.165642E+00
240  0.136667E+01  -.164777E+00
241  0.136327E+01  -.163824E+00
242  0.135943E+01  -.162800E+00
```

```
  243  0.135515E+01  -.161721E+00
  244  0.135044E+01  -.160600E+00
  245  0.134531E+01  -.159448E+00
  246  0.133977E+01  -.158277E+00
  247  0.133384E+01  -.157098E+00
  248  0.132751E+01  -.155916E+00
  249  0.132082E+01  -.154738E+00
  250  0.131378E+01  -.153568E+00
  251  0.130639E+01  -.152409E+00
  252  0.129869E+01  -.151262E+00
  253  0.129068E+01  -.150130E+00
  254  0.128239E+01  -.149014E+00
  255  0.127385E+01  -.147914E+00
  256  0.126506E+01  -.146826E+00
  257  0.125606E+01  -.145742E+00
  258  0.124687E+01  -.144654E+00
  259  0.123751E+01  -.143552E+00
  260  0.122802E+01  -.142427E+00
  261  0.121842E+01  -.141266E+00
  262  0.120873E+01  -.140058E+00
  263  0.119898E+01  -.138791E+00
  264  0.118921E+01  -.137446E+00
  265  0.117943E+01  -.136005E+00
  266  0.116969E+01  -.134445E+00
  267  0.116001E+01  -.132744E+00
  268  0.115042E+01  -.130888E+00
  269  0.114095E+01  -.128866E+00
  270  0.113162E+01  -.126677E+00
  271  0.112246E+01  -.124329E+00
  272  0.111347E+01  -.121843E+00
  273  0.110469E+01  -.119246E+00
  274  0.109611E+01  -.116571E+00
  275  0.108776E+01  -.113849E+00
  276  0.107966E+01  -.111105E+00
  277  0.107181E+01  -.108353E+00
  278  0.106423E+01  -.105606E+00
  279  0.105695E+01  -.102873E+00
  280  0.104999E+01  -.100164E+00
  281  0.104334E+01  -.974884E-01
  282  0.103704E+01  -.948540E-01
  283  0.103110E+01  -.922684E-01
  284  0.102552E+01  -.897401E-01
  285  0.102033E+01  -.872772E-01
  286  0.101553E+01  -.848852E-01
  287  0.101114E+01  -.825688E-01
  288  0.100717E+01  -.803330E-01
  289  0.100363E+01  -.781826E-01
  290  0.100053E+01  -.761234E-01
  291  0.997863E+00  -.741615E-01
  292  0.995651E+00  -.723023E-01
  293  0.993893E+00  -.705518E-01
  294  0.992595E+00  -.689135E-01
  295  0.991759E+00  -.673913E-01
  296  0.991387E+00  -.659880E-01 :(I1, COOR(:,I1),I=1,...,NVB)
  1   1   2   0
  2   2   3   0
  3   3   4   0
  4   4   5   0
  5   5   6   0
  6   6   7   0
  7   7   8   0
  8   8   9   0
  9   9  10   0
 10  10  11   0
 11  11  12   0
 12  12  13   0
 13  13  14   0
 14  14  15   0
 15  15  16   0
 16  16  17   0
 17  17  18   0
```

```
 18  18  19   0
 19  19  20   0
 20  20  21   0
 21  21  22   0
 22  22  23   0
 23  23  24   0
 24  24  25   0
 25  25  26   0
 26  26  27   0
 27  27  28   0
 28  28  29   0
 29  29  30   0
 30  30  31   0
 31  31  32   0
 32  32  33   0
 33  33  34   0
 34  34  35   0
 35  35  36   0
 36  36  37   0
 37  37  38   0
 38  38  39   0
 39  39  40   0
 40  40   1   0
 41  41  42   0
 42  42  43   0
 43  43  44   0
 44  44  45   0
 45  45  46   0
 46  46  47   0
 47  47  48   0
 48  48  49   0
 49  49  50   0
 50  50  51   0
 51  51  52   0
 52  52  53   0
 53  53  54   0
 54  54  55   0
 55  55  56   0
 56  56  57   0
 57  57  58   0
 58  58  59   0
 59  59  60   0
 60  60  61   0
 61  61  62   0
 62  62  63   0
 63  63  64   0
 64  64  65   0
 65  65  66   0
 66  66  67   0
 67  67  68   0
 68  68  69   0
 69  69  70   0
 70  70  71   0
 71  71  72   0
 72  72  73   0
 73  73  74   0
 74  74  75   0
 75  75  76   0
 76  76  77   0
 77  77  78   0
 78  78  79   0
 79  79  80   0
 80  80  81   0
 81  81  82   0
 82  82  83   0
 83  83  84   0
 84  84  85   0
 85  85  86   0
 86  86  87   0
 87  87  88   0
 88  88  89   0
```

```
  89  89  90   0
  90  90  91   0
  91  91  92   0
  92  92  93   0
  93  93  94   0
  94  94  95   0
  95  95  96   0
  96  96  97   0
  97  97  98   0
  98  98  99   0
  99  99 100   0
 100 100 101   0
 101 101 102   0
 102 102 103   0
 103 103 104   0
 104 104 105   0
 105 105 106   0
 106 106 107   0
 107 107 108   0
 108 108 109   0
 109 109 110   0
 110 110 111   0
 111 111 112   0
 112 112 113   0
 113 113 114   0
 114 114 115   0
 115 115 116   0
 116 116 117   0
 117 117 118   0
 118 118 119   0
 119 119 120   0
 120 120 121   0
 121 121 122   0
 122 122 123   0
 123 123 124   0
 124 124 125   0
 125 125 126   0
 126 126 127   0
 127 127 128   0
 128 128 129   0
 129 129 130   0
 130 130 131   0
 131 131 132   0
 132 132 133   0
 133 133 134   0
 134 134 135   0
 135 135 136   0
 136 136 137   0
 137 137 138   0
 138 138 139   0
 139 139 140   0
 140 140 141   0
 141 141 142   0
 142 142 143   0
 143 143 144   0
 144 144 145   0
 145 145 146   0
 146 146 147   0
 147 147 148   0
 148 148 149   0
 149 149 150   0
 150 150 151   0
 151 151 152   0
 152 152 153   0
 153 153 154   0
 154 154 155   0
 155 155 156   0
 156 156 157   0
 157 157 158   0
 158 158 159   0
 159 159 160   0
```

```
160 160 161   0
161 161 162   0
162 162 163   0
163 163 164   0
164 164 165   0
165 165 166   0
166 166 167   0
167 167 168   0
168 168  41   0
169 169 170   0
170 170 171   0
171 171 172   0
172 172 173   0
173 173 174   0
174 174 175   0
175 175 176   0
176 176 177   0
177 177 178   0
178 178 179   0
179 179 180   0
180 180 181   0
181 181 182   0
182 182 183   0
183 183 184   0
184 184 185   0
185 185 186   0
186 186 187   0
187 187 188   0
188 188 189   0
189 189 190   0
190 190 191   0
191 191 192   0
192 192 193   0
193 193 194   0
194 194 195   0
195 195 196   0
196 196 197   0
197 197 198   0
198 198 199   0
199 199 200   0
200 200 201   0
201 201 202   0
202 202 203   0
203 203 204   0
204 204 205   0
205 205 206   0
206 206 207   0
207 207 208   0
208 208 209   0
209 209 210   0
210 210 211   0
211 211 212   0
212 212 213   0
213 213 214   0
214 214 215   0
215 215 216   0
216 216 217   0
217 217 218   0
218 218 219   0
219 219 220   0
220 220 221   0
221 221 222   0
222 222 223   0
223 223 224   0
224 224 225   0
225 225 226   0
226 226 227   0
227 227 228   0
228 228 229   0
229 229 230   0
230 230 231   0
```

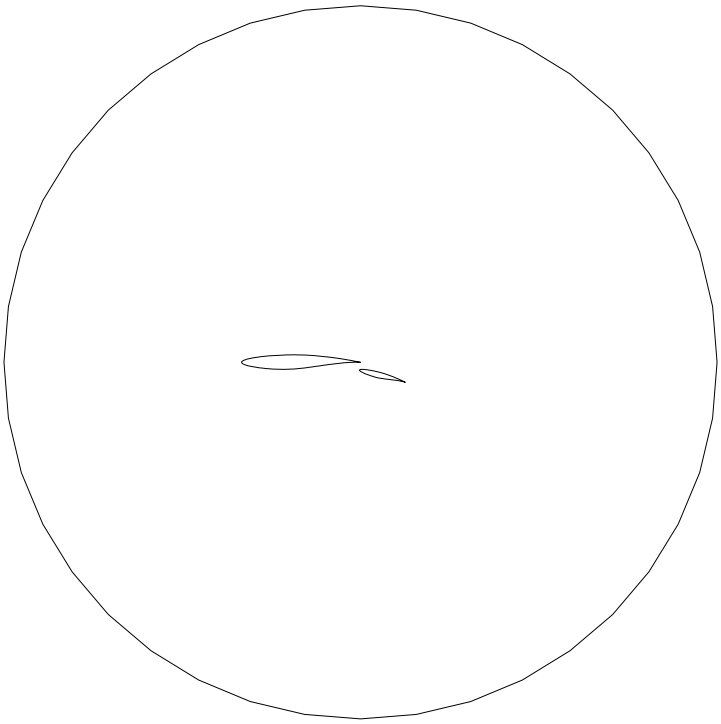
```
 231 231 232   0
 232 232 233   0
 233 233 234   0
 234 234 235   0
 235 235 236   0
 236 236 237   0
 237 237 238   0
 238 238 239   0
 239 239 240   0
 240 240 241   0
 241 241 242   0
 242 242 243   0
 243 243 244   0
 244 244 245   0
 245 245 246   0
 246 246 247   0
 247 247 248   0
 248 248 249   0
 249 249 250   0
 250 250 251   0
 251 251 252   0
 252 252 253   0
 253 253 254   0
 254 254 255   0
 255 255 256   0
 256 256 257   0
 257 257 258   0
 258 258 259   0
 259 259 260   0
 260 260 261   0
 261 261 262   0
 262 262 263   0
 263 263 264   0
 264 264 265   0
 265 265 266   0
 266 266 267   0
 267 267 268   0
 268 268 269   0
 269 269 270   0
 270 270 271   0
 271 271 272   0
 272 272 273   0
 273 273 274   0
 274 274 275   0
 275 275 276   0
 276 276 277   0
 277 277 278   0
 278 278 279   0
 279 279 280   0
 280 280 281   0
 281 281 282   0
 282 282 283   0
 283 283 284   0
 284 284 285   0
 285 285 286   0
 286 286 287   0
 287 287 288   0
 288 288 289   0
 289 289 290   0
 290 290 291   0
 291 291 292   0
 292 292 293   0
 293 293 294   0
 294 294 295   0
 295 295 296   0
 296 296 169   0  :(I1, EDGE(:,I1), I=1,...,NEDGE)
'N'               :Printing option 'Y' or 'N'
```

10.3 Program Results

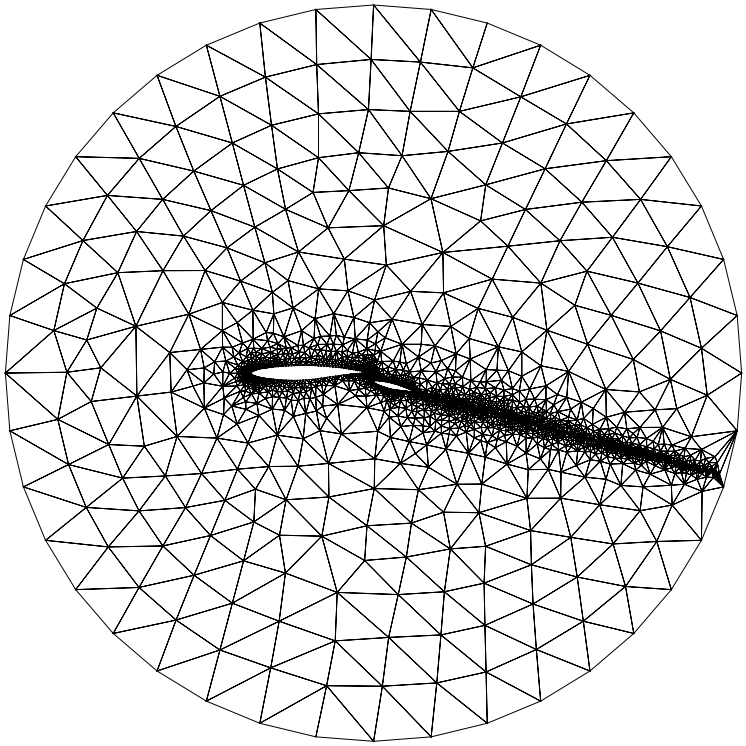
```
nag_mesh2d_delaunay (d06abc) Example Program Results

 Mesh characteristics with npropa =    -5
 nv   =  2317
 nelt =  4340
 Mesh characteristics with npropa =    -1
 nv   =  4420
 nelt =  8546
 Mesh characteristics with npropa =     1
 nv   =  5081
 nelt =  9868
 Mesh characteristics with npropa =     5
 nv   =  2015
 nelt =  3736
```

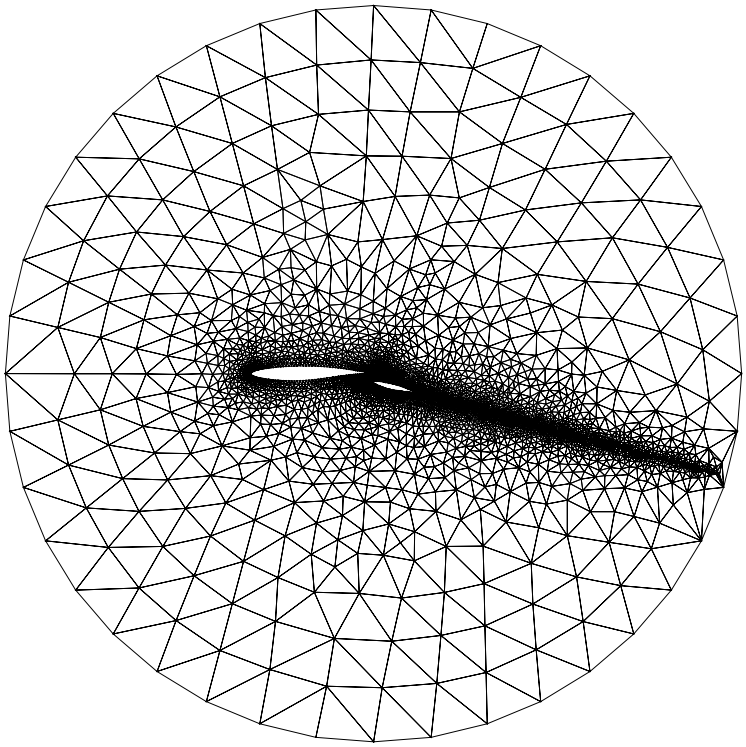
Example Program
Geometry for Generating Meshes



Mesh Generated Using Arithmetic Coefficient ω=1.2



Mesh Generated Using Arithmetic Coefficient ω=1.0



Mesh Generated Using Geometric Coefficient ω=1.0