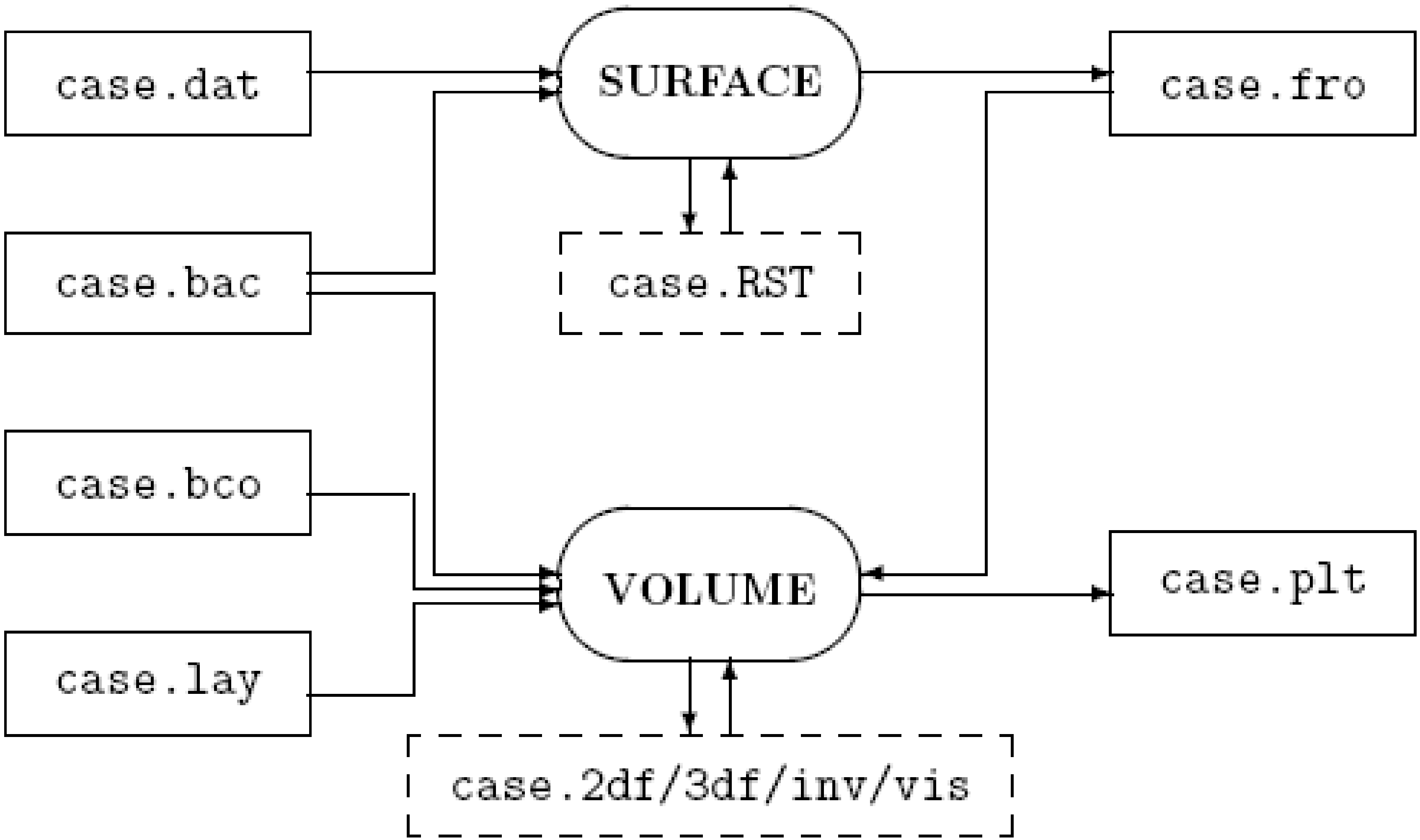
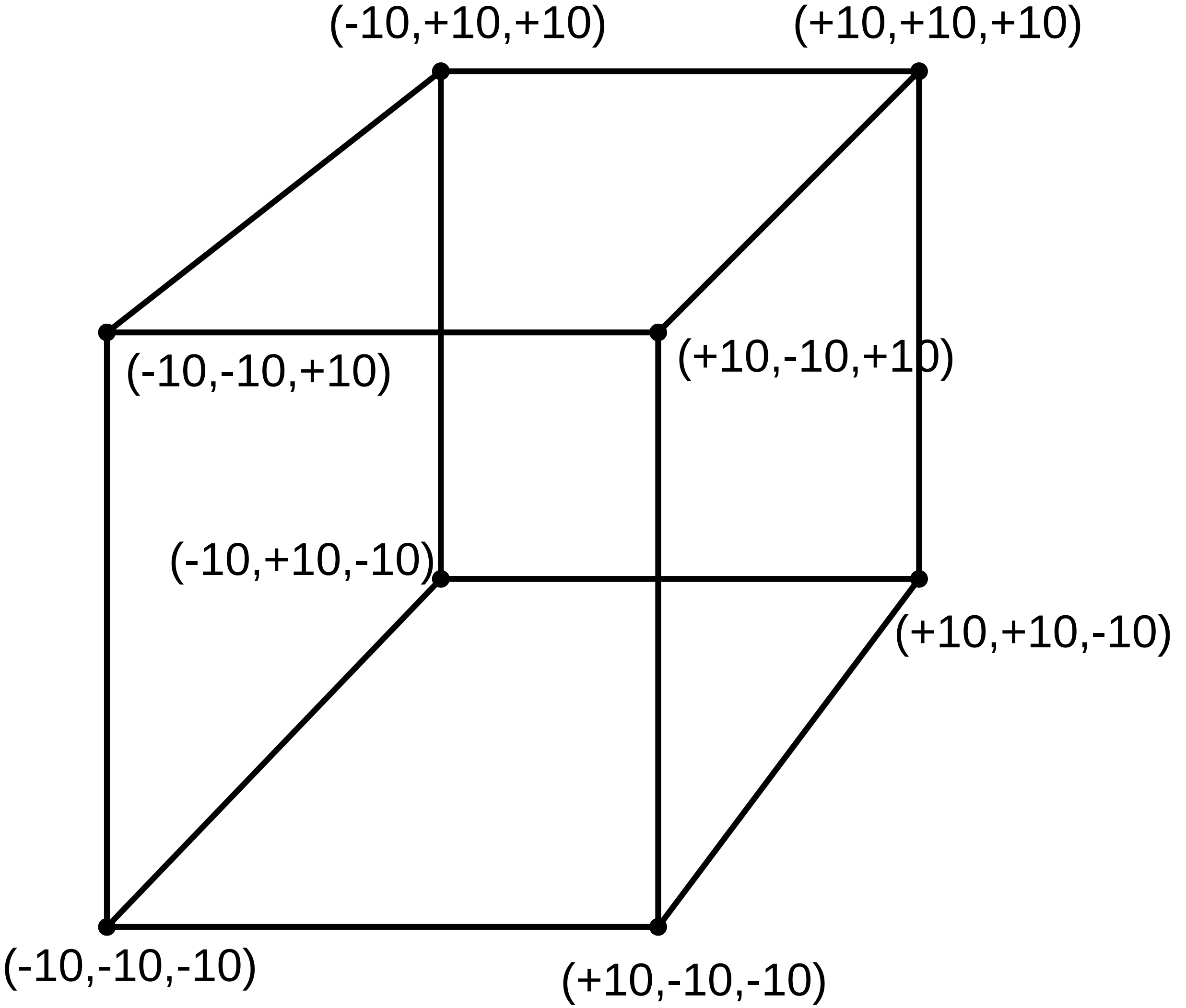

case.dat
SURFACE
case.fro
case.bac
case.RST
case.bco
VOLUME
case.plt
case.lay
case.2df/3df/inv/vis

Generating a Simple Cube

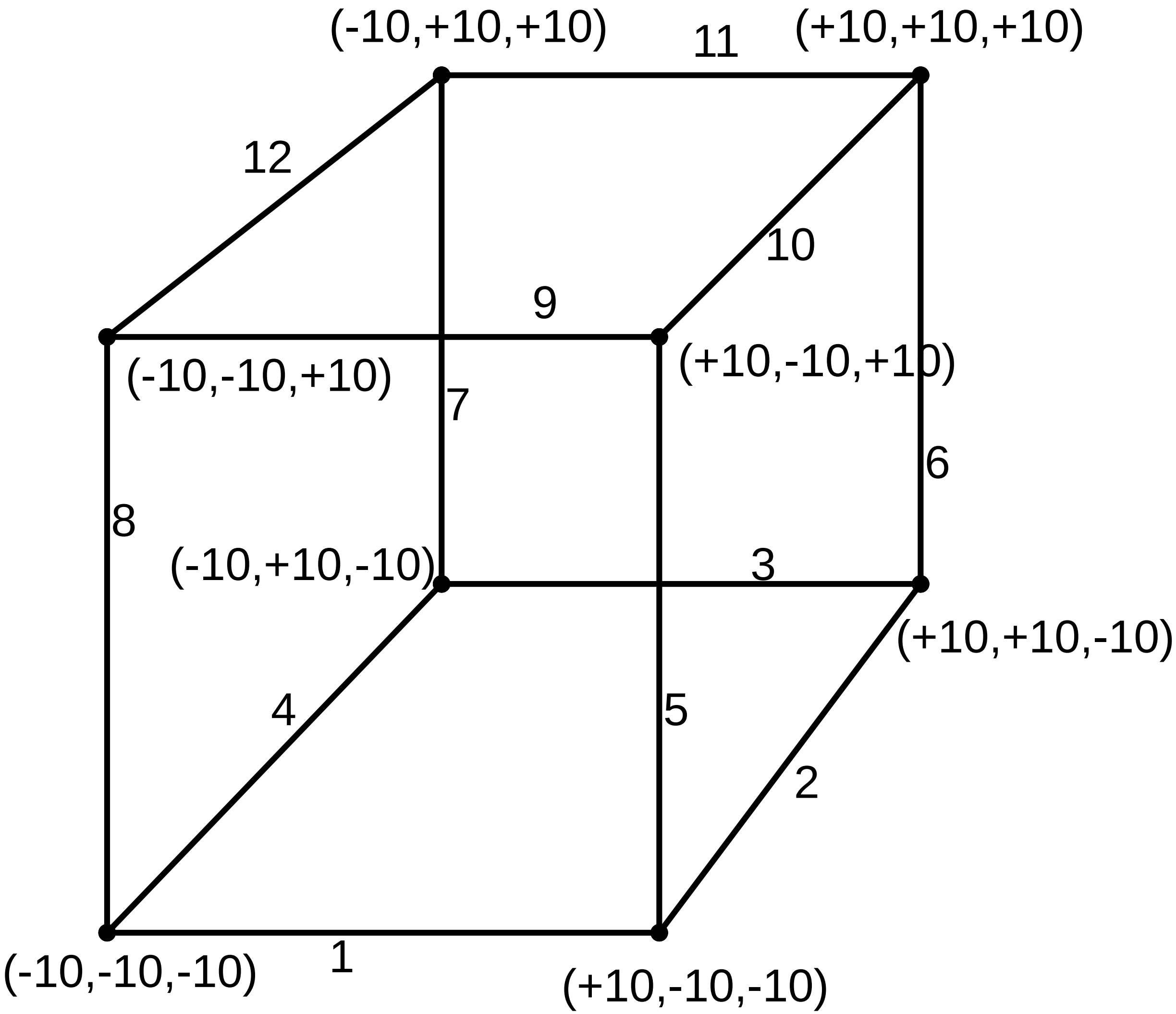
Cube

12 6

Guide to the .dat geometry file format

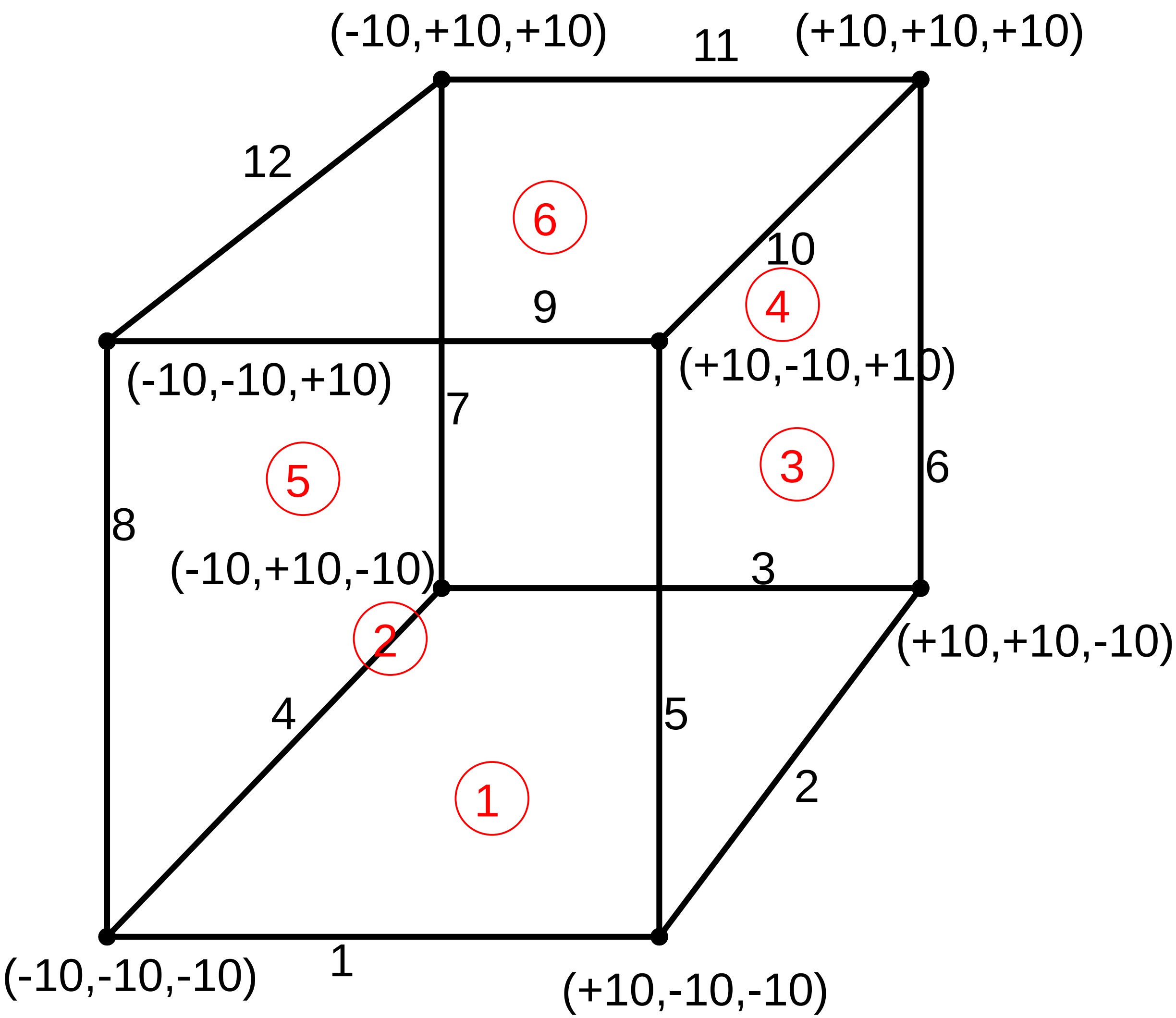


Guide to the .dat geometry file format




```
Cube
12    6
Curve Specification
1      1
2
-10   -10  -10
10    -10  -10
2      1
2
10    -10  -10
10    10  -10
3      1
2
10    10  -10
-10  10  -10
4      1
2
-10  -10  -10
-10  10  -10
5      1
2
.
.
.
```

Guide to the .dat geometry file format



.

.

Support Surface Specification

1 1

2 2

-10 -10 -10

10 -10 -10

-10 10 -10

10 10 -10

2 1

2 2

-10 -10 -10

10 -10 -10

-10 -10 10

10 -10 10

3 1

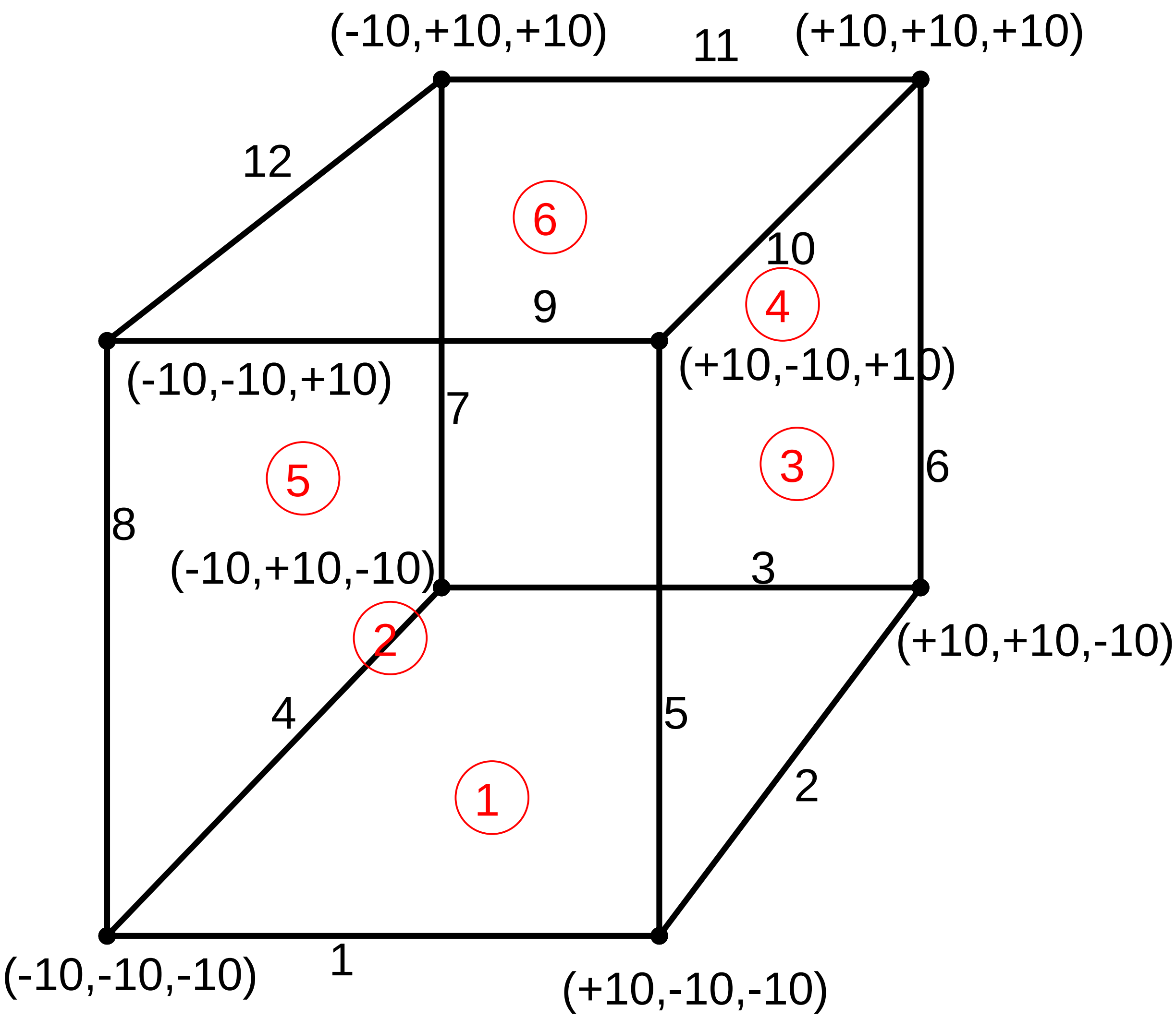
2 2

.

.

.

Guide to the .dat geometry file format



.

.

.

Connectivity Data

12 6

Curve Segments

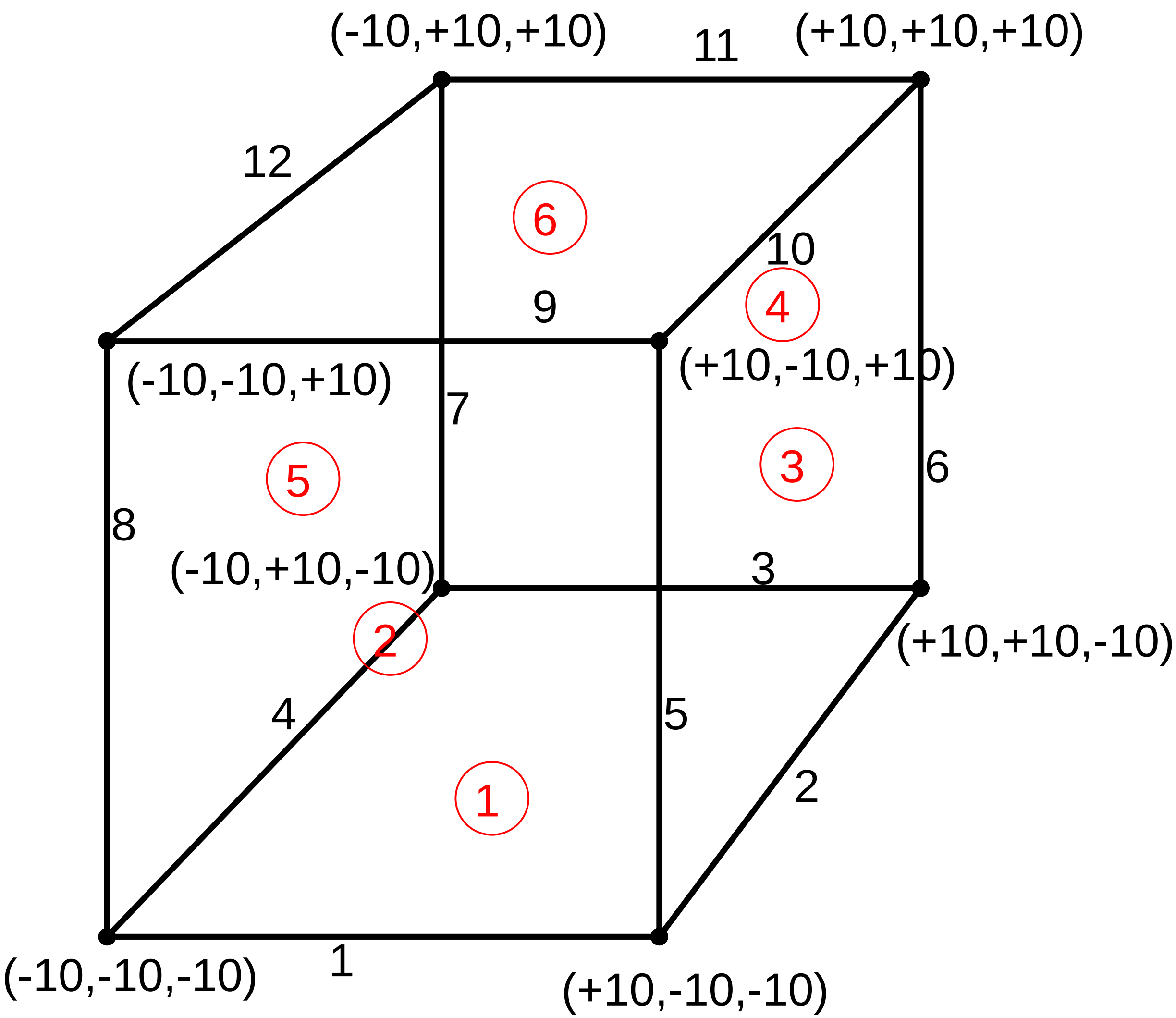
1	1	1
2	2	1
3	3	1
4	4	1
5	5	1
6	6	1
7	7	1
8	8	1
9	9	1
10	10	1
11	11	1
12	12	1

.

.

.

Guide to the .dat geometry file format



.

.

Surface Boundary Data

1	1	1	1
4			
1	2	3	4
2	2	1	1
4			
1	5	9	8
3	3	1	1
4			
2	6	10	5
4	4	1	1
4			

.

.

.

Cube

12 6

Curve Specification

1 1

2

-10 -10 -10

10 -10 -10

2 1

2

10 -10 -10

10 10 -10

3 1

2

10 10 -10

-10 10 -10

4 1

2

-10 -10 -10

-10 10 -10

5 1

2

.

.

.

.

.

Support Surface Specification

1 1

2 2

-10 -10 -10

10 -10 -10

-10 10 -10

10 10 -10

2 1

2 2

-10 -10 -10

10 -10 -10

-10 -10 10

10 -10 10

3 1

2 2

.

.

.

.

.

.

Connectivity Data

12 6

Curve Segments

1 1 1

2 2 1

3 3 1

4 4 1

5 5 1

6 6 1

7 7 1

8 8 1

9 9 1

10 10 1

11 11 1

12 12 1

.

.

.

.

.

Surface Boundary Data

1 1 1 1

4

1 2 3 4

2 2 1 1

4

1 5 9 8

3 3 1 1

4

2 6 10 5

4 4 1 1

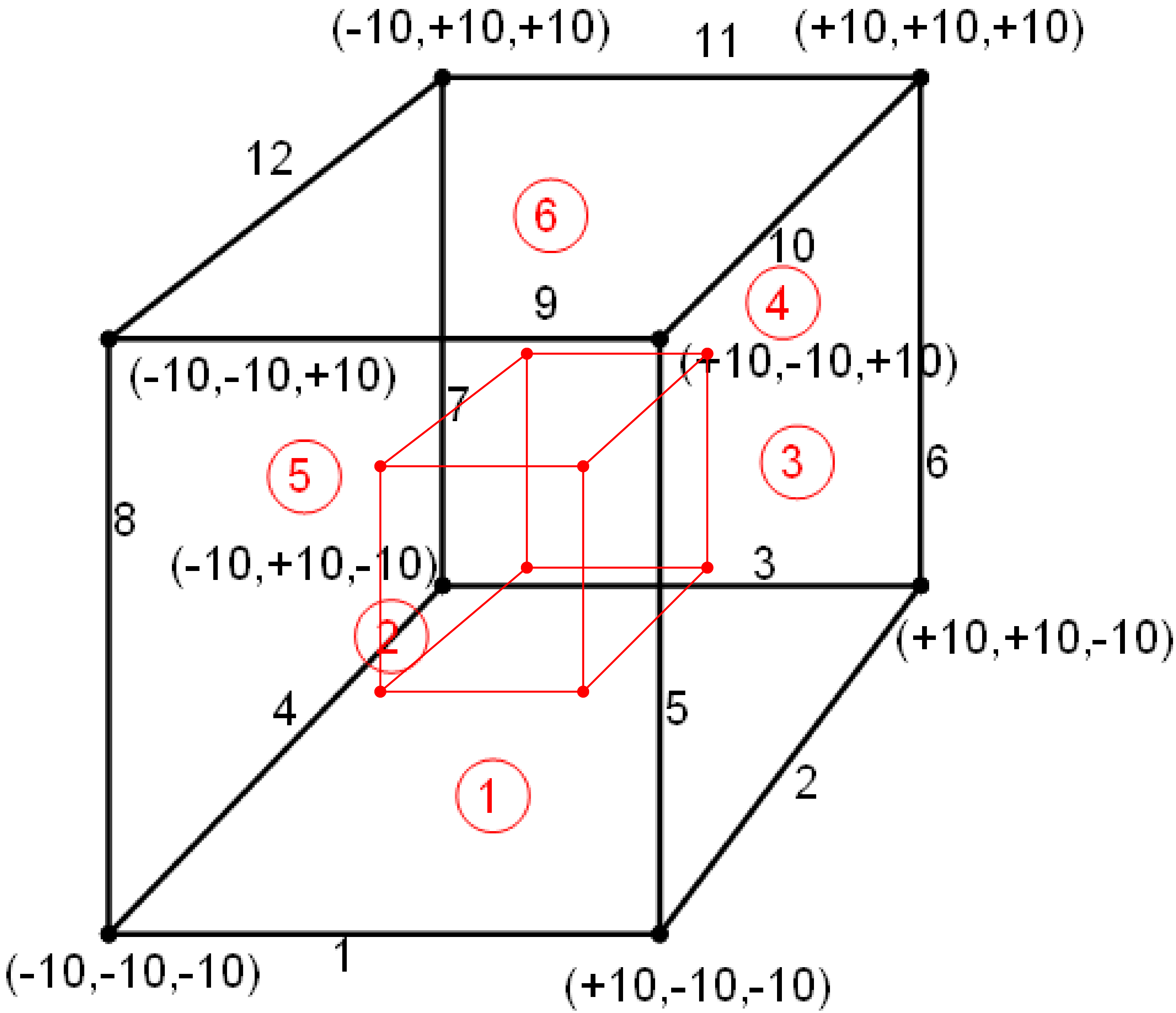
4

.

.

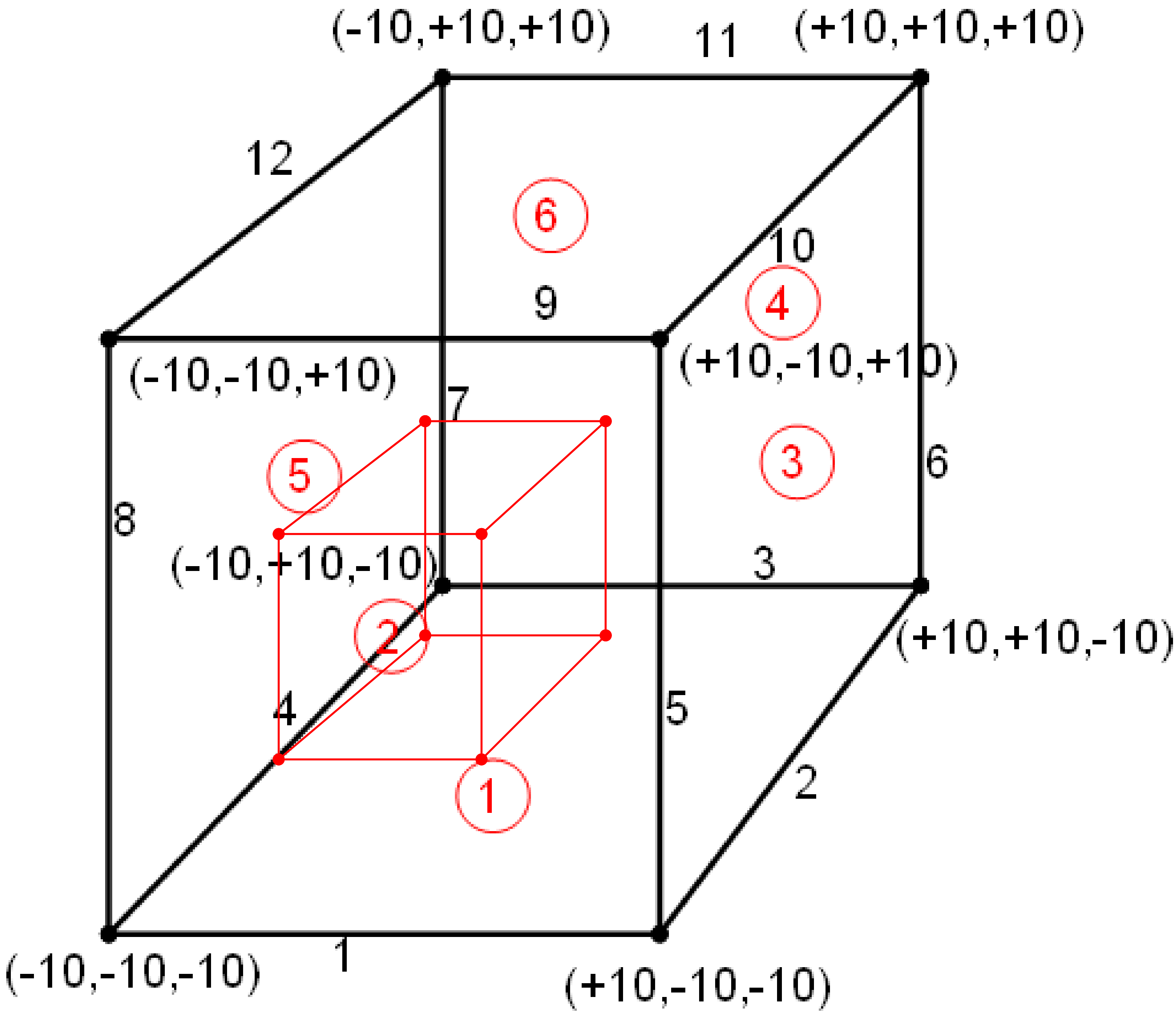
.

Generating a
Cube within a Cube

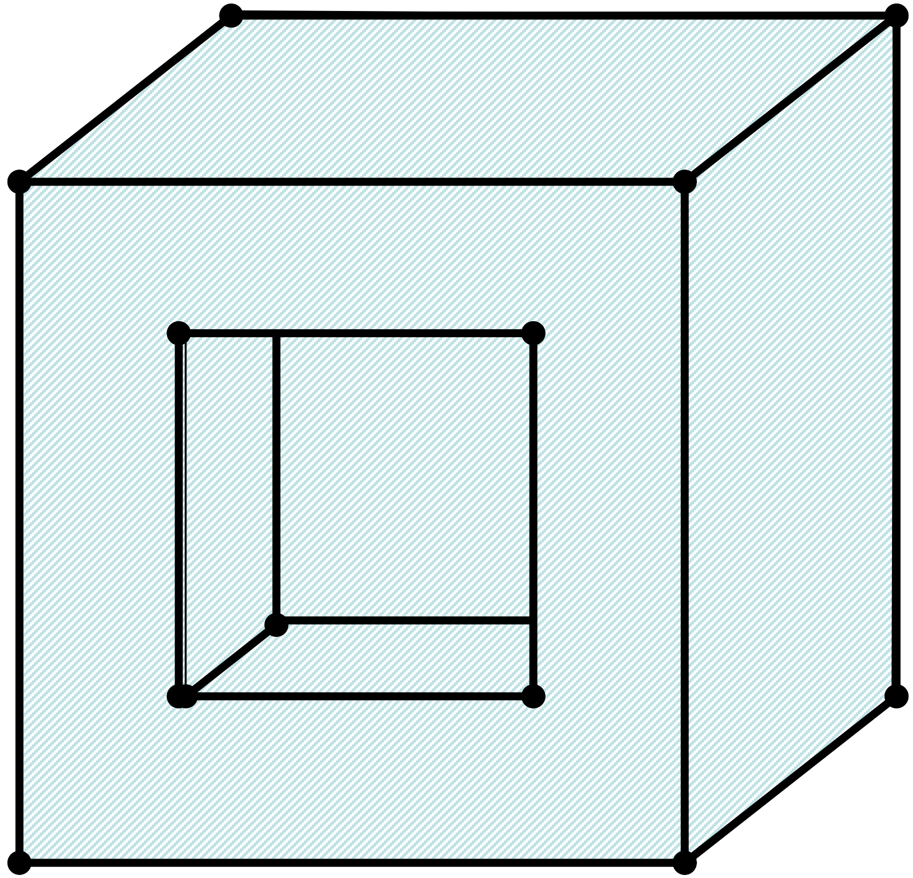

(-10,+10,+10)
11
(+10,+10,+10)
12
6
10
9
4
(-10,-10,+10)
(+10,-10,+10)
7
5
3
6
8
(-10,+10,-10)
3
2
(+10,+10,-10)
4
5
1
2
1
(-10,-10,-10)
(+10,-10,-10)

```
* background mesh
   8     6  0  0  0
         1          -100          -100          -100
  1.0          0.0          0.0          2.0
 0.0           1.0          0.0          2.0
 0.0           0.0          1.0          2.0
         2           100          -100          -100
  1.0          0.0          0.0          2.0
 0.0           1.0          0.0          2.0
 0.0           0.0          1.0          2.0
         3           100           100          -100
  1.0          0.0          0.0          2.0
 0.0           1.0          0.0          2.0
 0.0           0.0          1.0          2.0
         4          -100           100          -100
  1.0          0.0          0.0          2.0
 0.0           1.0          0.0          2.0
 0.0           0.0          1.0          2.0
         5          -100          -100           100
  1.0          0.0          0.0          2.0
 0.0           1.0          0.0          2.0
 0.0           0.0          1.0          2.0
         6           100          -100           100
  1.0          0.0          0.0          2.0
 0.0           1.0          0.0          2.0
 0.0           0.0          1.0          2.0
         7           100           100           100
  1.0          0.0          0.0          2.0
 0.0           1.0          0.0          2.0
 0.0           0.0          1.0          2.0
         8          -100           100           100
  1.0          0.0          0.0          2.0
 0.0           1.0          0.0          2.0
 0.0           0.0          1.0          2.0
.
.
.
.
.
        1        1        2        4        8
        2        1        2        8        6
        3        1        6        8        5
        4        2        3        4        7
        5        2        7        4        8
        6        2        7        8        6
* points
* lines
* triangles
```

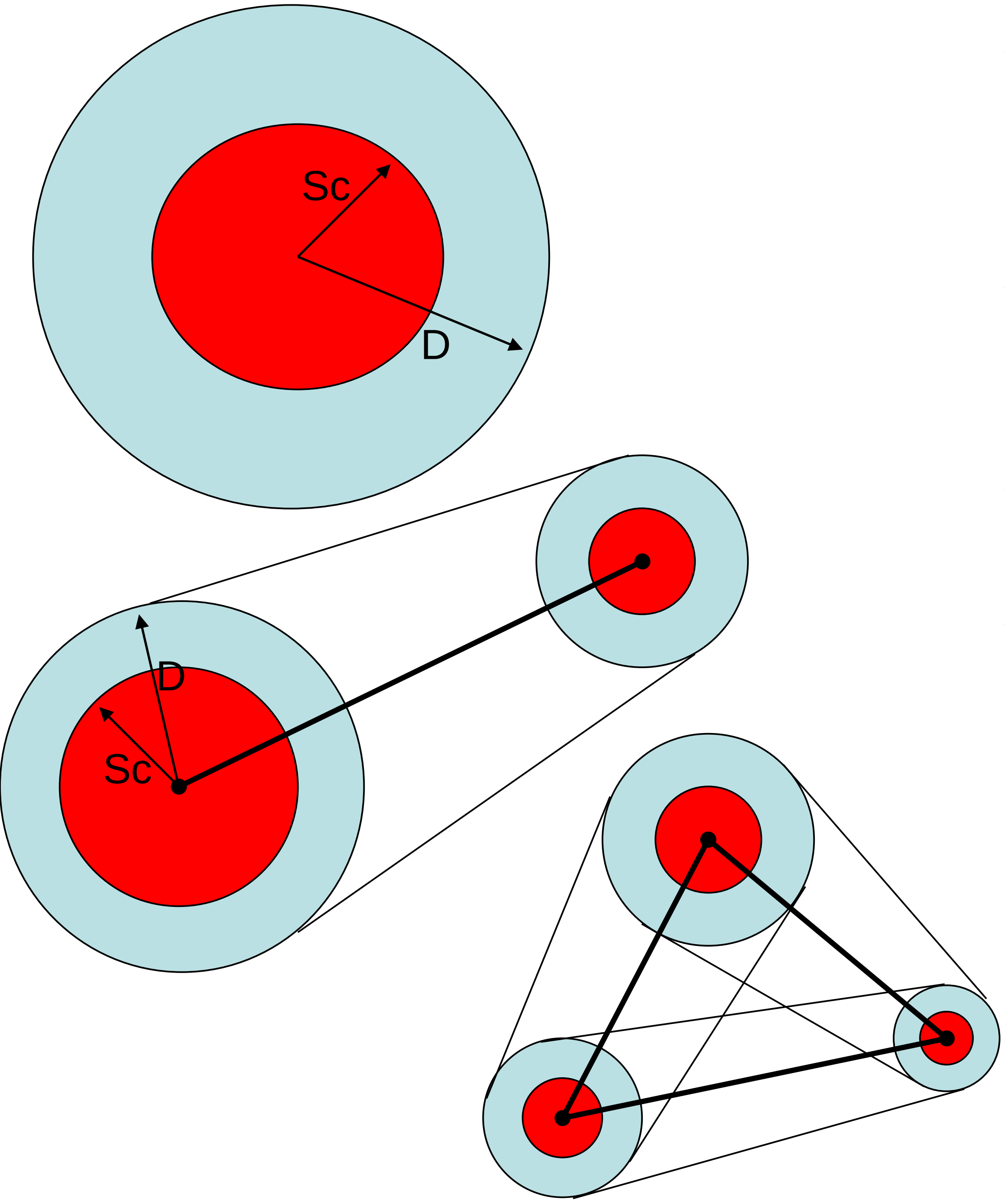
Using Trimmed Surfaces



(-10,+10,+10)
11
(+10,+10,+10)
12
6
10
9
4
(-10,-10,+10)
(+10,-10,+10)
7
5
3
6
8
(-10,+10,-10)
3
2
(+10,+10,-10)
4
5
1
2
(-10,-10,-10)
1
(+10,-10,-10)



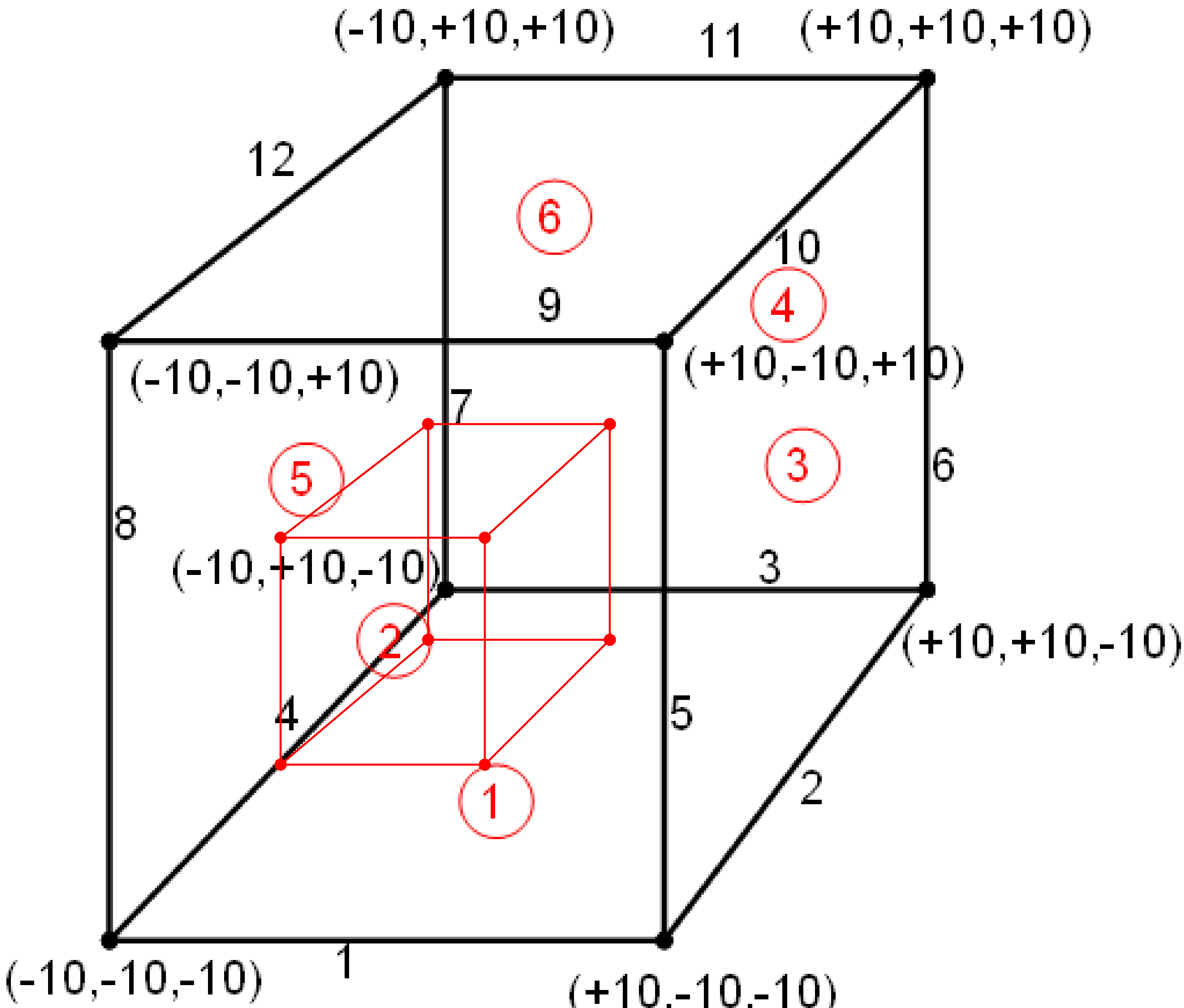
Defining Mesh Point Density (Point, Line and Triangle Sources)

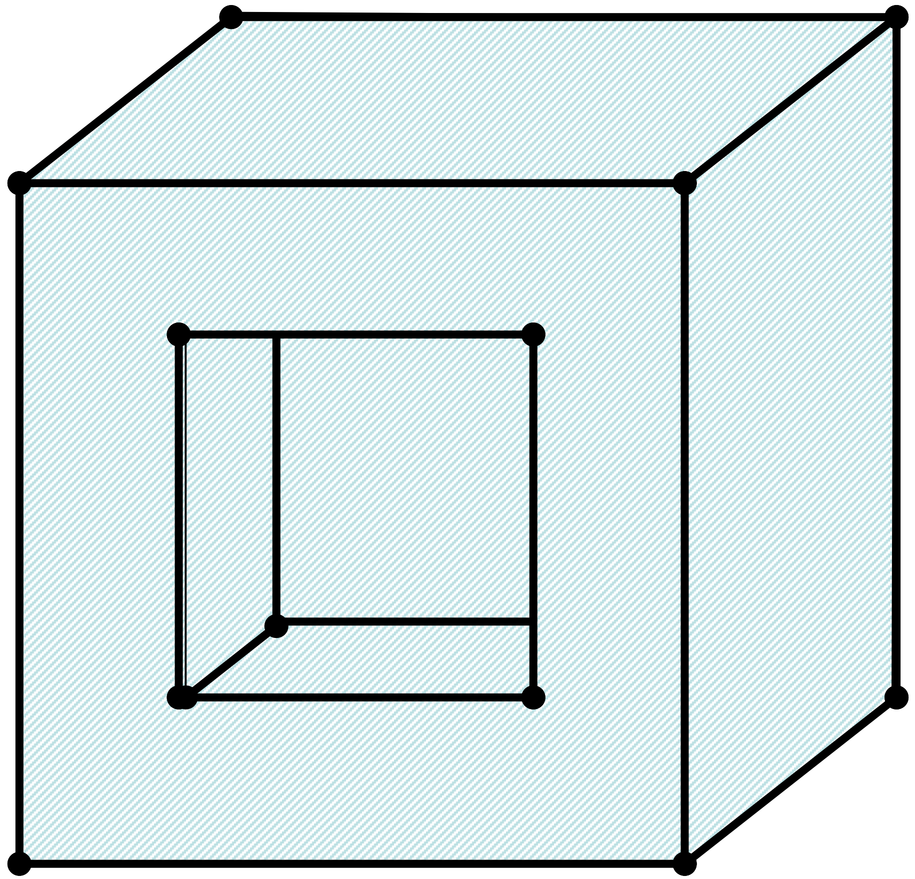


* background mesh
8 6 2 1 1
.
.
.

* Points
Point 1
-10 -10 -10 1.0 3.0 5.0
Point 2
-10 10 -10 1.0 2.0 4.0
Point 2
* Lines
Line 1
-10 -10 10 0.5 1.0 3.0
-10 10 10 0.2 0.5 2.0
* Triangles
Planar 1
10 -10 -10 1.0 2.0 4.0
10 10 -10 0.5 4.0 6.0
10 10 10 0.3 1.0 3.0

Using Trimmed Surfaces


(-10,+10,+10)
11
(+10,+10,+10)
12
6
10
9
4
(-10,-10,+10)
(+10,-10,+10)
7
5
3
6
8
(-10,+10,-10)
3
2
(+10,+10,-10)
4
5
1
2
(-10,-10,-10)
1
(+10,-10,-10)



Surface Mesh File Format

```
c
c *** opens surface triangulation data file
c
      open(inp,file='case.fro',form='formatted')
c
c *** reads the triangulation definition
c
      read(inp,*) ne,np,idum,idum,ncv,nsf,nshet,nwire
c
c *** coordinates of the nodes
c
      do 100 ip=1,npst
      read(inp,*) jp,(xst(i),i=1,3)
  100 continue
c
c *** connectivities of the triangular faces
c
      do 200 ie=1,nest
      read(inp,*) je,(kst(i),i=1,4)
  200 continue
c
c *** parametric coordinate u of nodes in the curves
c
      do 300 ic=1,ncv
      read(inp,*) jc,npcv
      read(inp,*) (kncv(i),xu(i),i=1,npcv)
  300 continue
c
c *** parametric coordinates (v,w) of nodes in the surfaces
c
      do 400 is=1,nsf
      read(inp,20) js,npsf
      read(inp,70) (knsf(i),xv(i),xw(i),i=1,npsf)
  400 continue
```

```
c
c *** reads curve geometry definition coefficients
c
      do 600 is=1,ncv
      read(inp,*) js,nu
      do 500 ip=1,nu
      read(inp,*) (rcv(i),i=1,6)
  500 continue
  600 continue
c
c *** reads surface geometry definition coefficients
c
      do 800 is = 1,nsf
      read(inp,*) js,nv,nw
      do 700 ip=1,nv*nw
      read(inp,*) (rsf(i),i=1,12)
  700 continue
  800 continue
c
c *** closes surface triangulation file
c
      close(inp)
```

.fro file

Volume Mesh File Format

```
open( inp, file='case.plt', form='unformatted')

read(inp)  numTetrahedra, numNodes, numTriangles
read(inp)  ((tets(in,ie),ie=1,numTetrahedra),in=1,4)

read(inp)  ((coor(in,ip),ip=1,numNodes,),in=1,3)

read(inp)  ((tris(in,ie),ie=1,numTriangles),in=1,5)

close(inp)
```

Column 5 is the Surface Number

Tetrahedral .plt file

```
open( inp, file='case.plt', form='unformatted')

read(inp)  totalNumElements, numNodes, totalNumBndFaces, numHexahedra,
           numPrisms, numPyramids, numTetrahedra, numQuads, numTriangles
read(inp)  ((hexs(in,ie),ie=1,numHexahedra),in=1,8)
read(inp)  ((prisms(in,ie),ie=1,numPrisms),in=1,6)
read(inp)  ((pyramids(in,ie),ie=1,numPyramids),in=1,5)
read(inp)  ((tets(in,ie),ie=1,numTetrahedra),in=1,4)

read(inp)  ((coor(in,ip),ip=1,numNodes),in=1,3)

read(inp)  ((quads(in,if),if=1,numQuads),in=1,5)
read(inp)  ((tris(in,ie),ie=1,numTriangles),in=1,5)

close(inp)
```

Column 5 is the Surface Number

Hybrid .plt file

.gco File Format

.gco file

`Line of Text`

Boundary Condition Flags

$nsf \quad ncv$

- nsf: No of surface components
- ncv: No of curve components

`Line of Text`

○ Surface Components

$$knsf^{(1)} \quad ktsf^{(1)}$$
$$\vdots$$
$$knsf^{(i)} \quad ktsf^{(i)}$$
$$\vdots$$
$$knsf^{(nsf)} \quad ktsf^{(nsf)}$$

- $knsf^{(i)}$: Surface component number $(= i)$
- $ktsf^{(i)}$: Surface component boundary type:

  1 .... generate viscous layers
  2 .... re–generate surface mesh
  3 .... no change to surface mesh

- $ktsf^{(i)}$: Surface element type:

  + ... triangles
  - .... quadrilaterals

`Line of Text`

○ Curve Components

$$kncv^{(1)} \quad ktcv^{(1)} \quad kscv^{(1)}$$
$$\vdots$$
$$kncv^{(i)} \quad ktcv^{(i)} \quad kscv^{(i)}$$
$$\vdots$$
$$kncv^{(ncv)} \quad ktcv^{(ncv)} \quad kscv^{(ncv)}$$

- $kncv^{(i)}$: Curve component number $(= i)$
- $ktsf^{(i)}$: Curve component boundary type:

  0 .... curve is not on trailing edges
  1 .... curve is on trailing edges

- $ktsf^{(i)}$: Curve smoothing type:

  0 .... smooth using points on surfaces
  1 .... smooth using points on the same curve

Viscous Layers File Format

.lay file

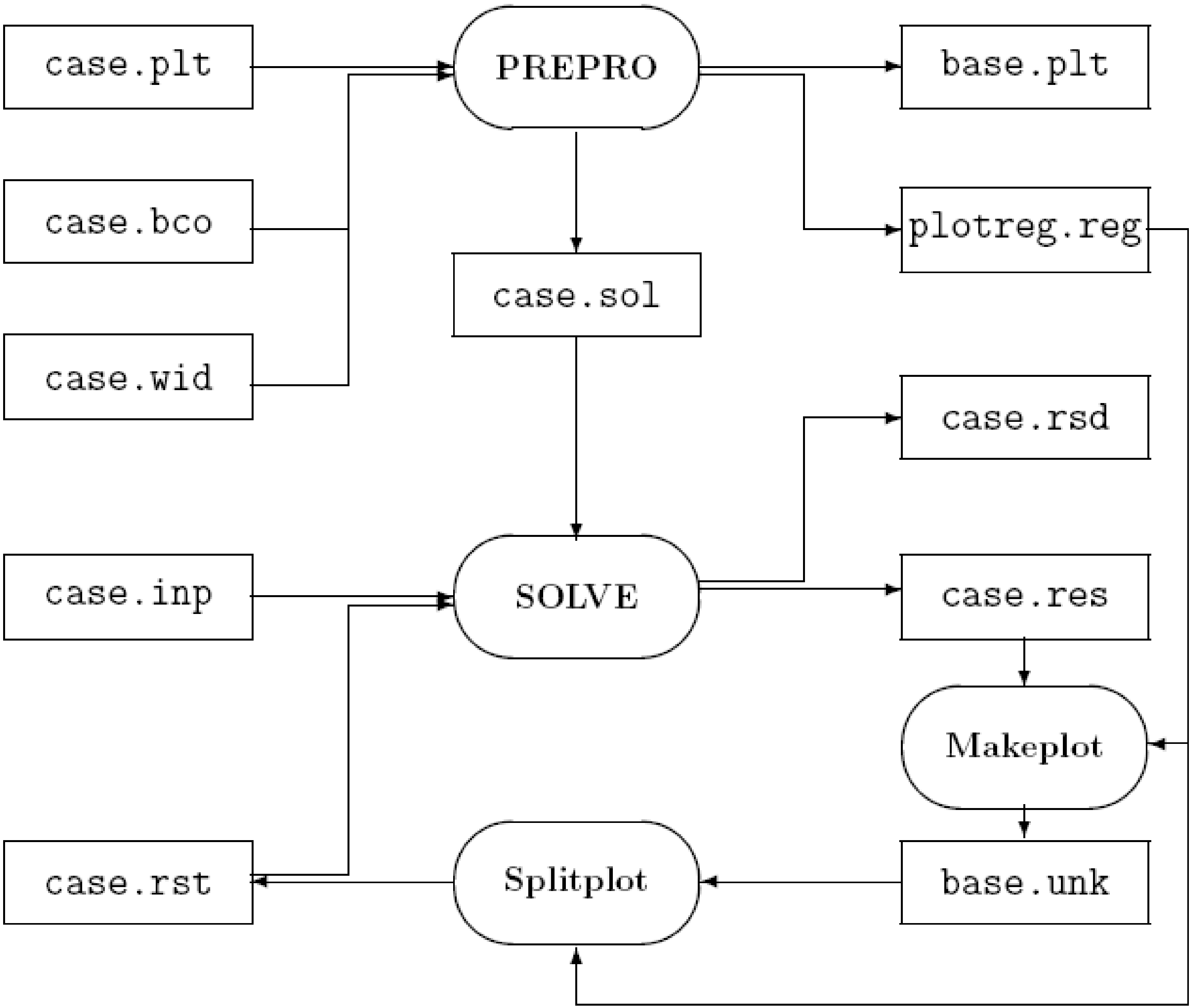
This file is a user generated file and it contains:

- the number of viscous layers
- the height of each layer

e.g.

```
10
0.001
0.002
0.003
0.005
0.008
0.012
0.016
0.020
0.025
0.030
```

Running the Flow Solver


case.plt
PREPRO
base.plt
case.bco
plotreg.reg
case.sol
case.wid
case.rsd
case.inp
SOLVE
case.res
Makeplot
case.rst
Splitplot
base.unk

.bco file

Line of Text	Boundary Condition Flags
$nsf \quad ncv$	• nsf: No of surface components • ncv: No of curve components
Line of Text	○ Surface Components
$knsf^{(1)} \quad ktsf^{(1)}$ $\vdots$ $knsf^{(i)} \quad ktsf^{(i)}$ $\vdots$ $knsf^{(nsf)} \quad ktsf^{(nsf)}$	• $knsf^{(i)}$: Surface component number $(= i)$ • $ktsf^{(i)}$: Surface component boundary type: 1 .... wall 2 .... symmetry 3–4 ...... far field 5–6 ...... engine inlet 7–8 ...... engine outlet
Line of Text	○ Curve Components
$kncv^{(1)} \quad ktcv^{(1)}$ $\vdots$ $kncv^{(i)} \quad ktcv^{(i)}$ $\vdots$ $kncv^{(ncv)} \quad ktcv^{(ncv)}$	• $kncv^{(i)}$: Curve component number $(= i)$ • $ktsf^{(i)}$: Curve component boundary type. It depends on the number of singular nodes in the curve: 0 .... none is singular 1 .... all are singular 2 .... first and last are singular 3 .... only first is singular 4 .... only last is singular

.wid file

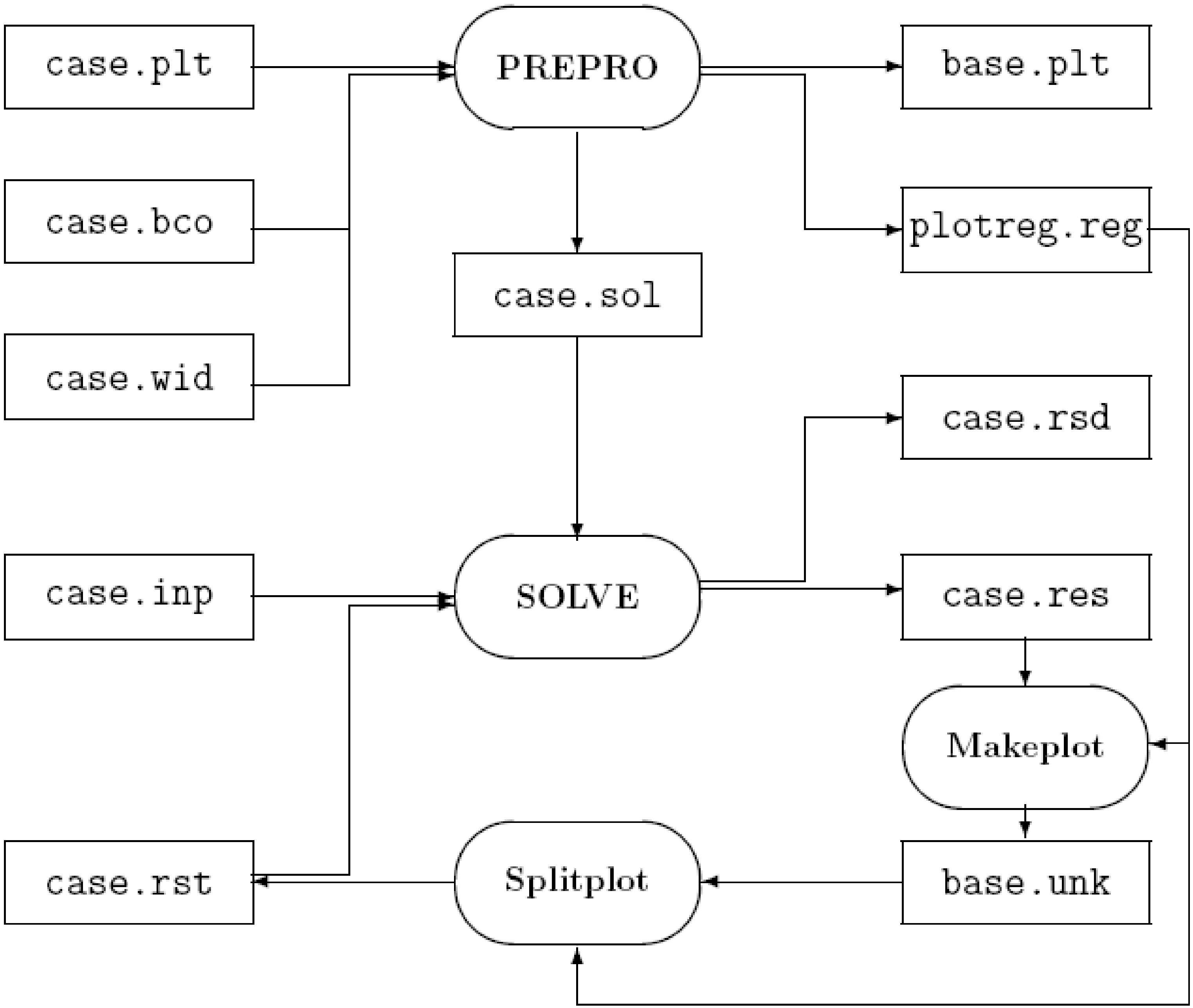
```
&control
 numberOftripLine = 0
 tripLineCoordinates(:,1) = 0.0
 tripLineCoordinates(:,2) = 0.0
 tripLineCoordinates(:,3) = 0.0
 tripLineCoordinates(:,4) = 0.0
 tripLineCoordinates(:,5) = 0.0
 tripLineCoordinates(:,6) = 0.0
 tripRadius = 1.0
 wallDistanceThickness = 0
&
```

Triggering Parameters

- `numberOfTripLine`: Total number of lines along which tripping will take place
- `tripLineCoordinates(:,1:3` : The coordinates of the starting point of the each line
- `tripLineCoordinates(:,4:6` : The coordinates of the end point of the each line
- `tripRadius`: Triggering will be evaluated for surface points which fall within this radius from the line

```
&inputVariables
 ivd%numberOfProcesses = 8,
 ivd%dataDirectory = '/HOME04/xuser/extoubay/Flite/data/Mgns3d/m6/Inv/'
 ivd%viscosityScheme = 1,
 ivd%numberOfMGIterations = -5,
 ivd%numberOfSGIterations = 0,
 ivd%numberOfGridsToUse = 3,
 ivd%numberOfTurbulenceGrids = 1,
 ivd%CFLNumber = 1.00,
 ivd%NumberOfCFLIncrements = 0,
 ivd%turbulentCFLNumber = 0.0,
 ivd%turbK = 0.01,
 ivd%maxTurbulenceValue = 3000.0,
 ivd%alpha =   3.06,
 ivd%beta =   0.00,
 ivd%MachNumber = 0.85,
 ivd%PrandtlNumber = 0.72,
 ivd%ReynoldsNumber = 0.0,
 ivd%gamma = 1.4,
 ivd%numberOfRelaxationSteps = 1,
 ivd%turbulenceModel = 0,
 ivd%triggerRadius = 100.,
 ivd%numberOfTriggerSteps = 0,
 ivd%turbulenceTriggerValue = 25.0,
 ivd%multigridScheme = 3,
 ivd%dissipationScheme = 2,
 ivd%coarseGridDissipationScheme = 2,
 ivd%secondOrderDissipationFactor = 0.4,
 ivd%fourthOrderDissipationFactor = 0.200,
 ivd%coarseGridDissipationFactor = 0.75,
 ivd%numberOfPSSteps = 0,
 ivd%multigridBCRelaxation = 1.0,
 ivd%prolongationRelaxation = 1.0,
 ivd%prolongationSmoothingFactor = 0.0,
 ivd%residualSmoothingFactor = 0.,
 ivd%prolongationMappingScheme = 1,
 ivd%useMatrixDissipation = .false.,
 ivd%writeToFileInterval = 50,
 ivd%useTimeResidual = .false.,
 ivd%wallsAreIsentropic = .true.,
 ivd%engineBCRelaxation = 0.0,
 ivd%numberOfEORelaxationSteps = 0,
/
```

.inp file


case.plt
PREPRO
base.plt
case.bco
plotreg.reg
case.sol
case.wid
case.rsd
case.inp
SOLVE
case.res
Makeplot
case.rst
Splitplot
base.unk

```
open( inp, file='case.unk', form='unformatted')

read(inp)  numNodes
read(inp)  ((unk(in,ip),ip=1,numNodes),in=1,5)

close(inp)
```

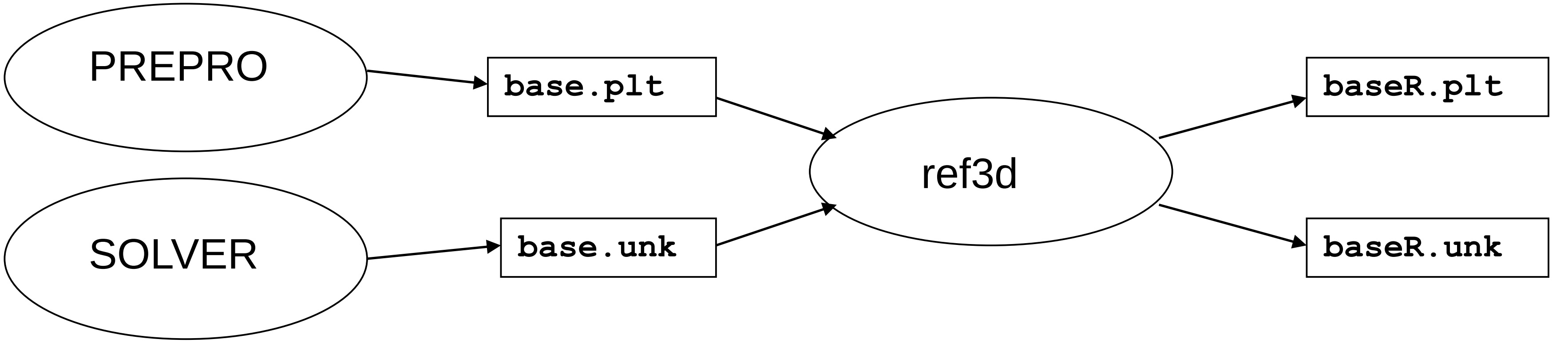
FLITE solution file format (.unk)

```
open( inp, file='case.plt', form='unformatted')

read(inp)  numElem, numNodes, numBoundFace
read(inp)  ((iel(in,ie),ie=1,numElem),in=1,4)
read(inp) ((coor(in,ip),ip=1,numNodes),in=1,3)
read(inp) ((iface(in,it),it=1,numBoundFace),in=1,5)

close(inp)
```

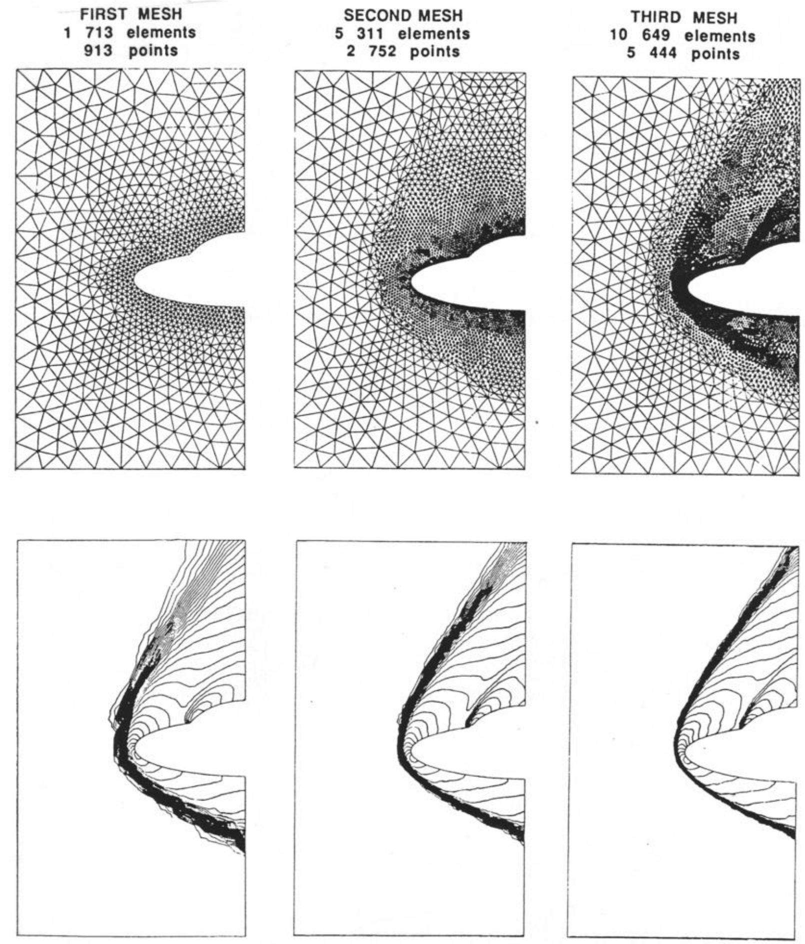
FLITE solution mesh format (.plt)

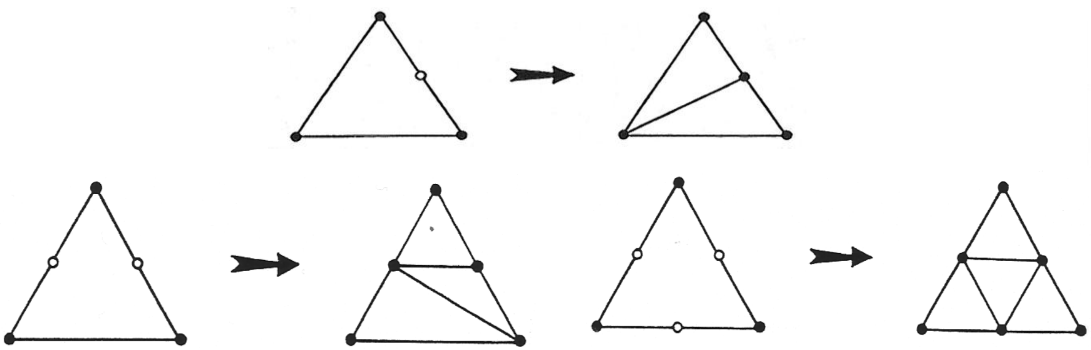

PREPRO
SOLVER
base.plt
base.unk
ref3d
baseR.plt
baseR.unk

Mesh Adaptation

Mesh Enrichment

- **Advantages:**
  - Simple and quick to implement
  - Trivial interpolation
- **Disadvantages:**
  - Multiple refinement results in large meshes
  - De-refinement require excessive storage
  - Incorporating stretching results is distorted elements
  - Not suitable for unsteady flow with moving components

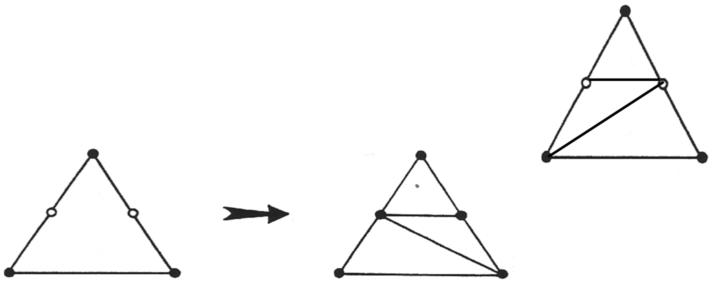




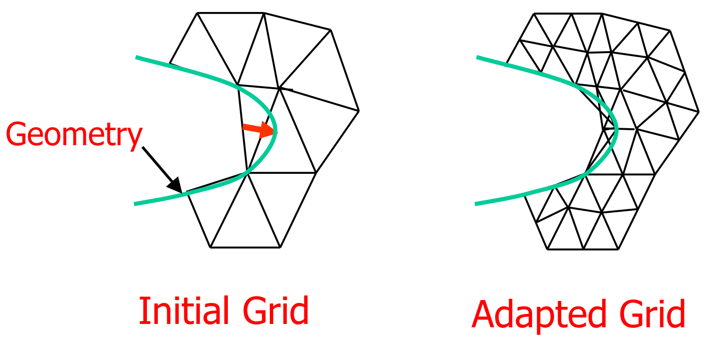
Mesh Adaptation

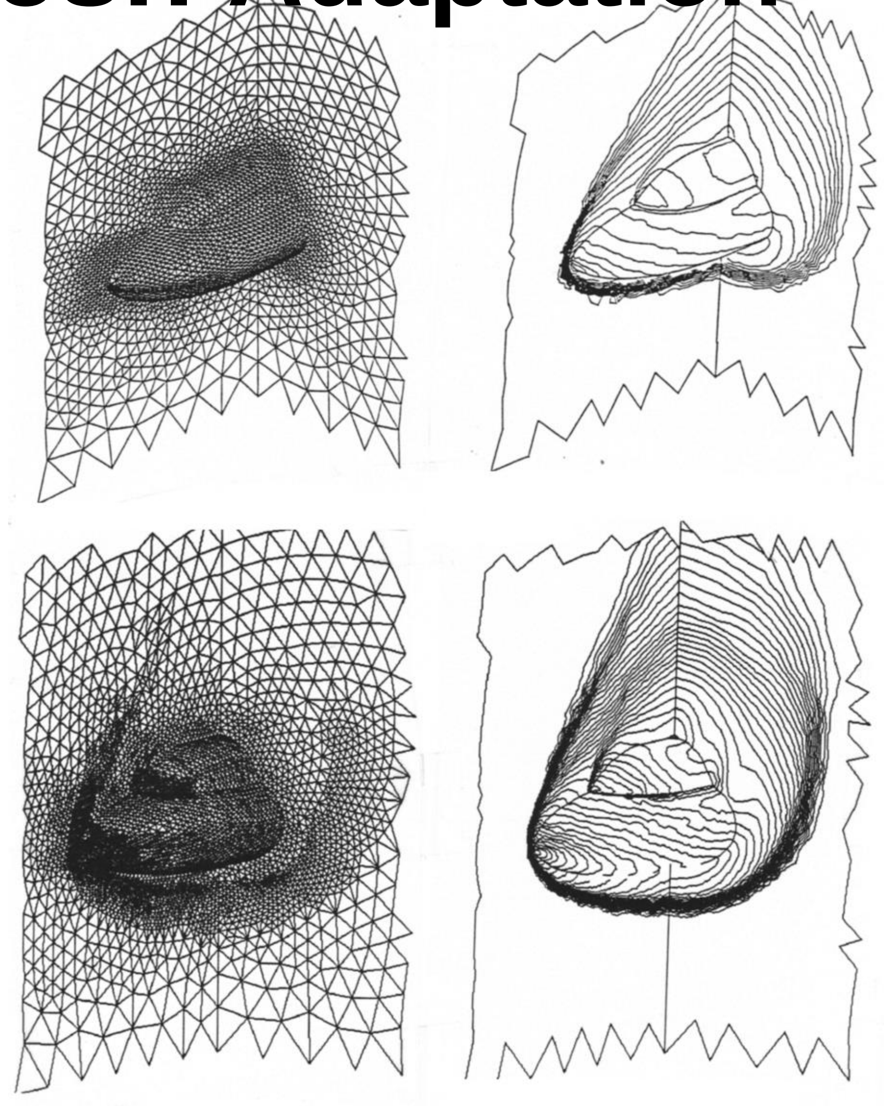
Mesh Enrichment

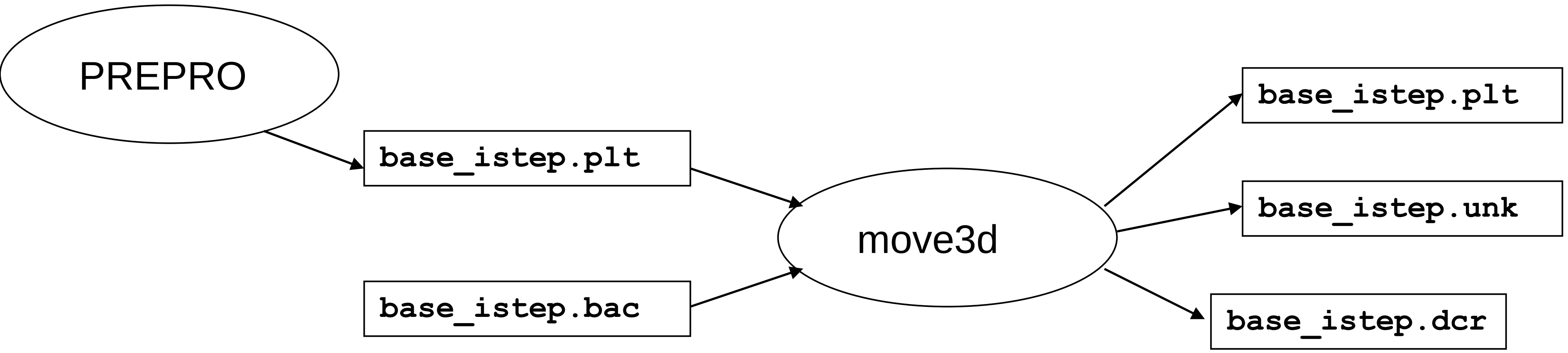
- Special care is required in 3D to ensure compatibility of adjacent elements



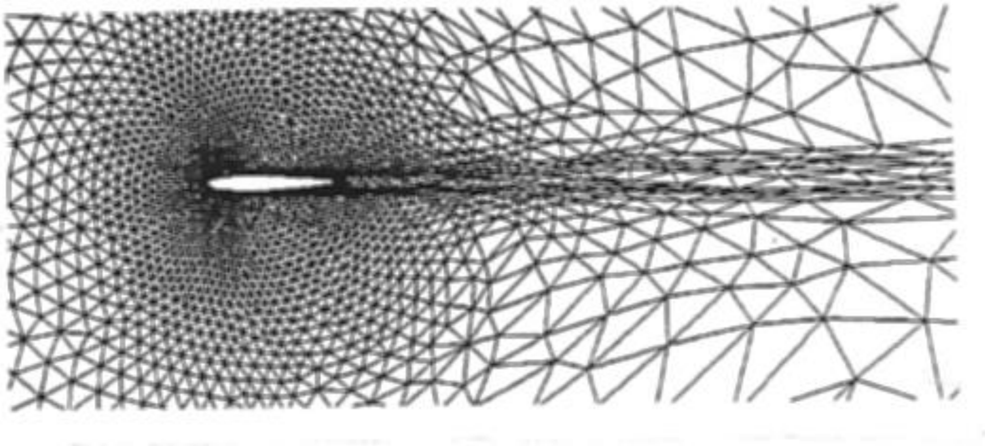
- Special care is also needed to ensure the validity of the mesh after projecting the added points onto the surface

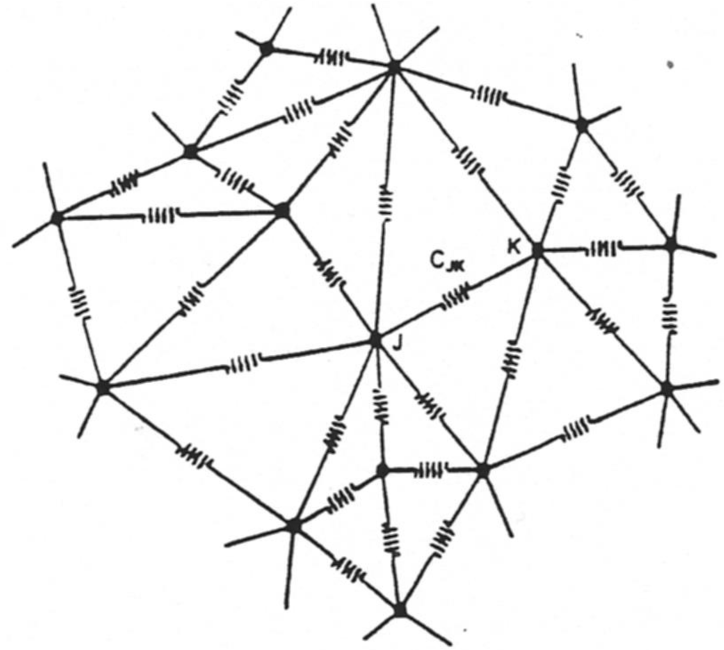


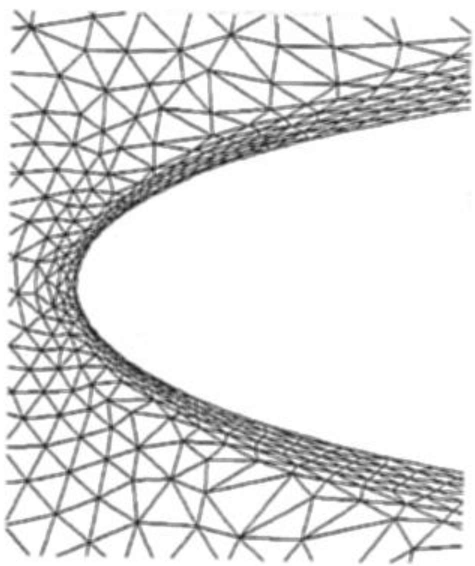


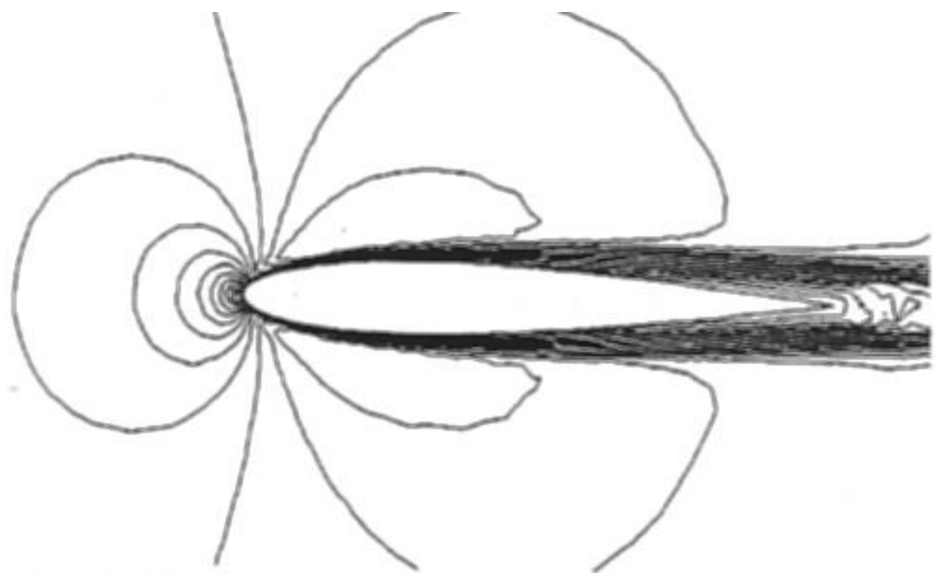

PREPRO
base_istep.plt
base_istep.bac
move3d
base_istep.plt
base_istep.unk
base_istep.dcr

Mesh Adaptation









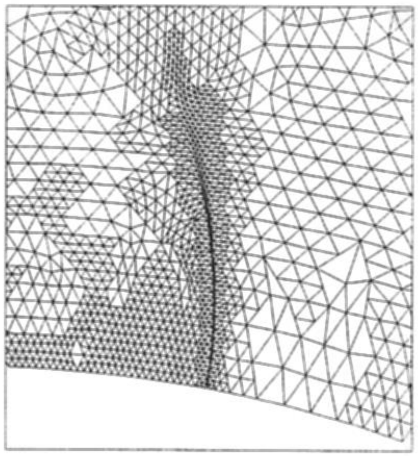
Mesh Movement

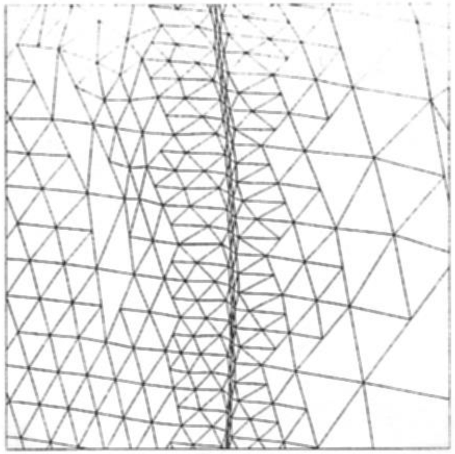
Mesh Adaptation

– **Advantages:**
  - Simple and quick to implement
  - Can handle moving components

– **Disadvantages:**
  - Expensive interpolation
  - Initial mesh may lack the required resolution to resolve all the flow features
  - Hard to control the quality of the moved mesh

– Coupling of mesh movement and mesh enrichment can over come most of the restrictions.





Unsteady Simulation

B60 Configuration

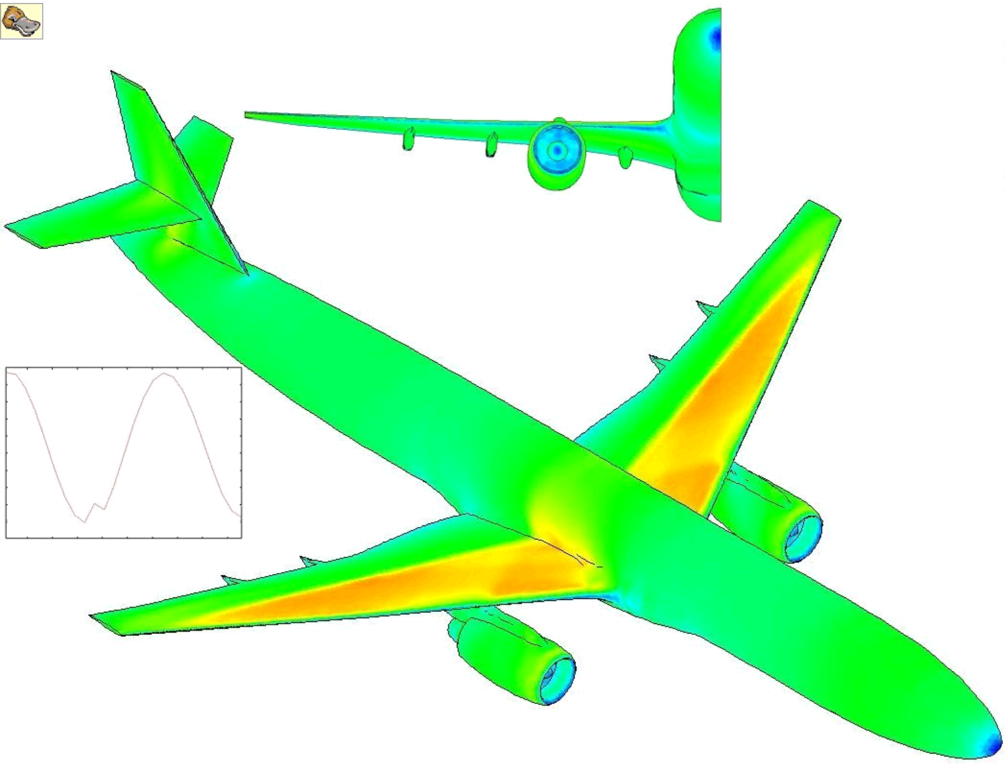
$M_\infty = 0.801 \quad a_0 = 2.78^0$

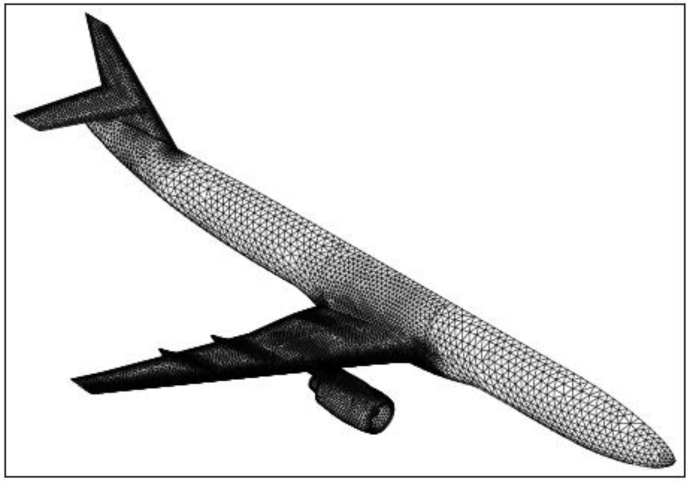
Reduced frequency of 0.0025

Piecewise linear **heave oscillations** with amplitude of 2% at mid wing and 6.5% at wing tip relative to semi-span

Piecewise linear **pitch oscillations** of 1^0 at mid wing and 5^0 at wing tip

16 steps per cycle



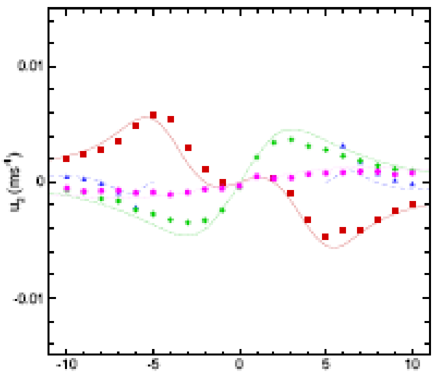


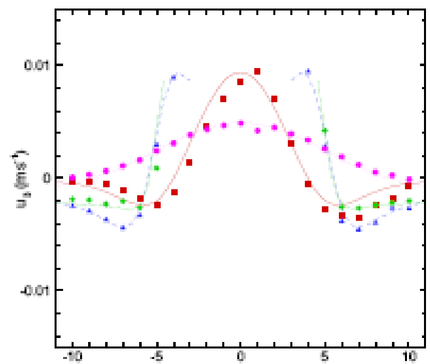
745198 Elements
135760 Points

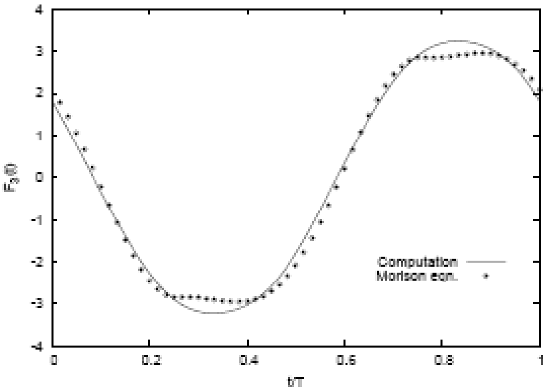
Unsteady Incompressible Navier Stokes

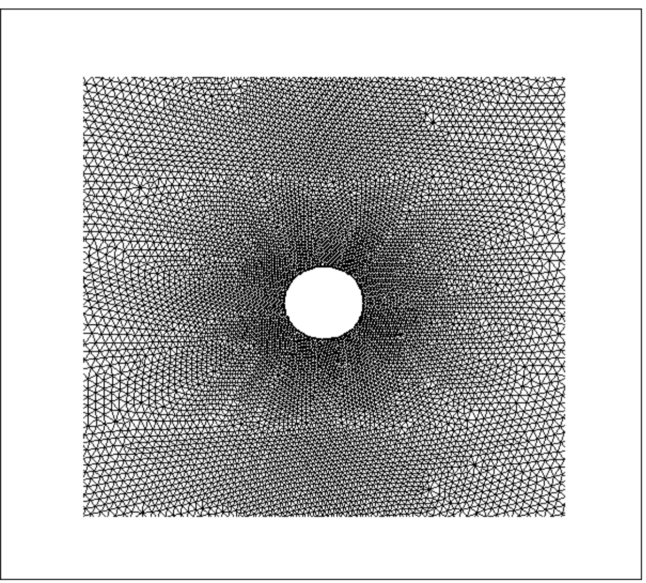
Flow over an oscillating cylinder Re=100

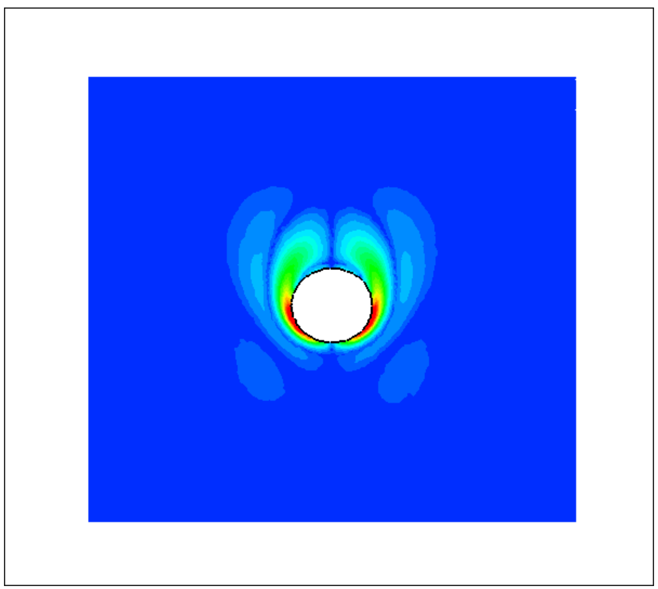
Cylinder is oscillating in a prescribed sinusoidal motion $\dot{x} = -A\sin(2\pi f t), \quad KC = \dfrac{2\pi A}{D} = 5$

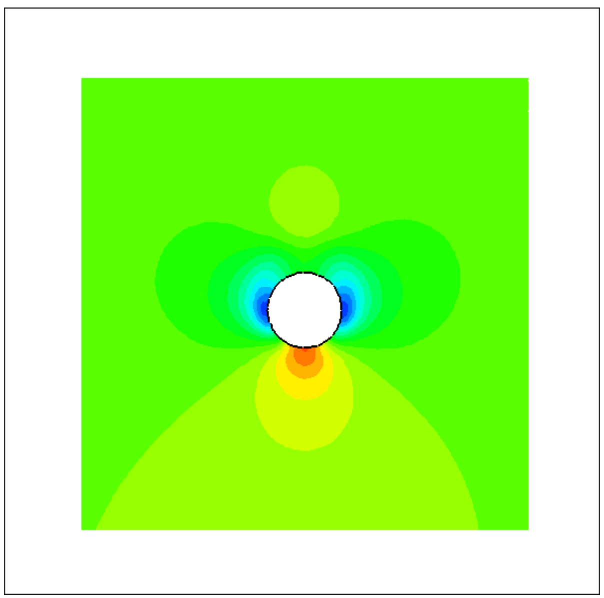


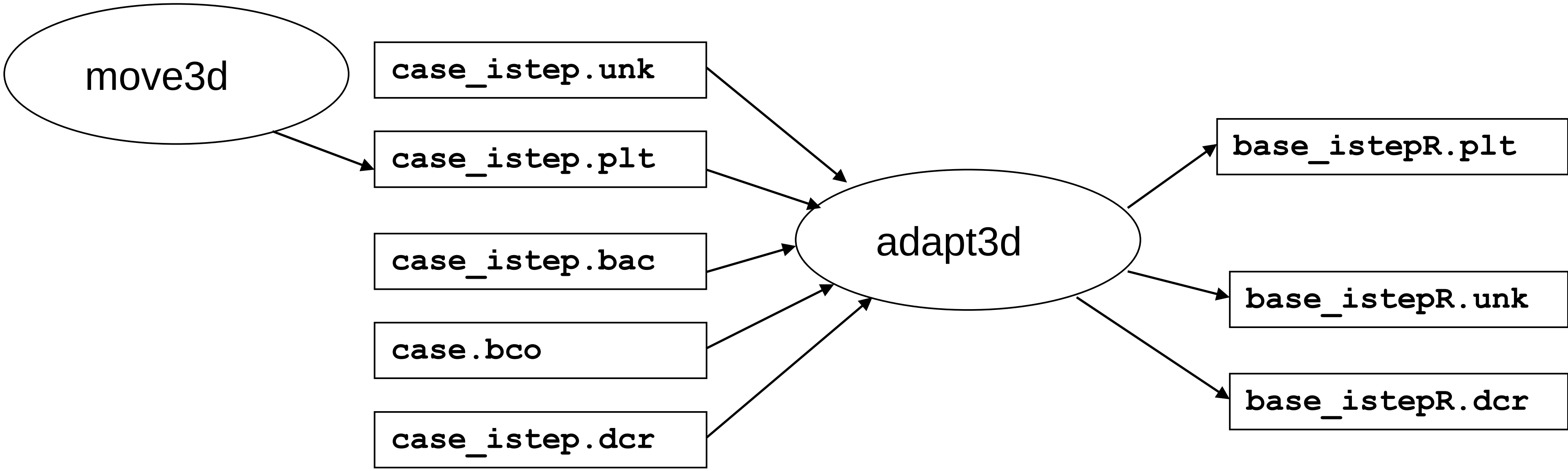




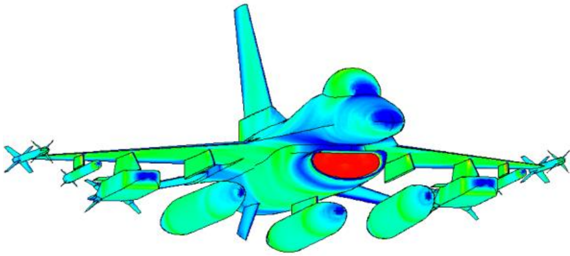







move3d
case_istep.unk
case_istep.plt
case_istep.bac
case.bco
case_istep.dcr
adapt3d
base_istepR.plt
base_istepR.unk
base_istepR.dcr

Unsteady Inviscid Flow



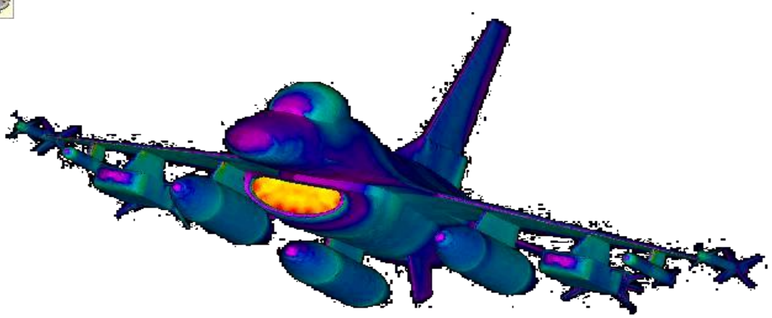
Store Separation Simulation

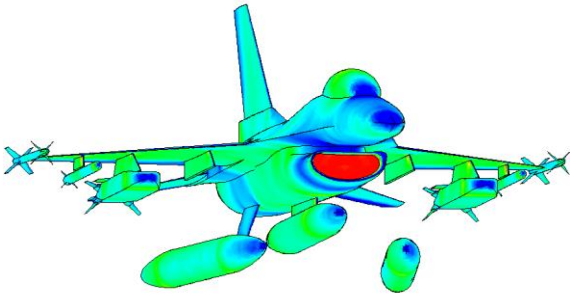
F16 Configuration

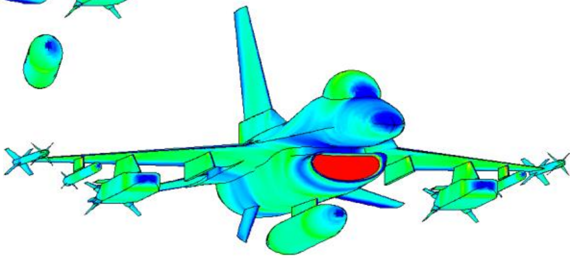
α_{init} = zero degrees
M= 0.5
Container motion computed

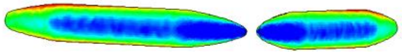
2.7 million tetrahedra

15 time steps
50 multigrid cycle per time step









8h Wall clock time
Solver: 16 R14000 CPUs
Preprocessing and adaption : 1 CPU